COMPUTER CROP MODELS AS A MANAGEMENT TOOL

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SugarSystems®

Scope

- Crop modelling History
- CANEGRO sugarcane model
- Evolution of a benchmarking tool
- Models as a management tool
  - Harvest Planning
  - Performance monitoring
  - Replant Planning
  - Irrigation scheduling

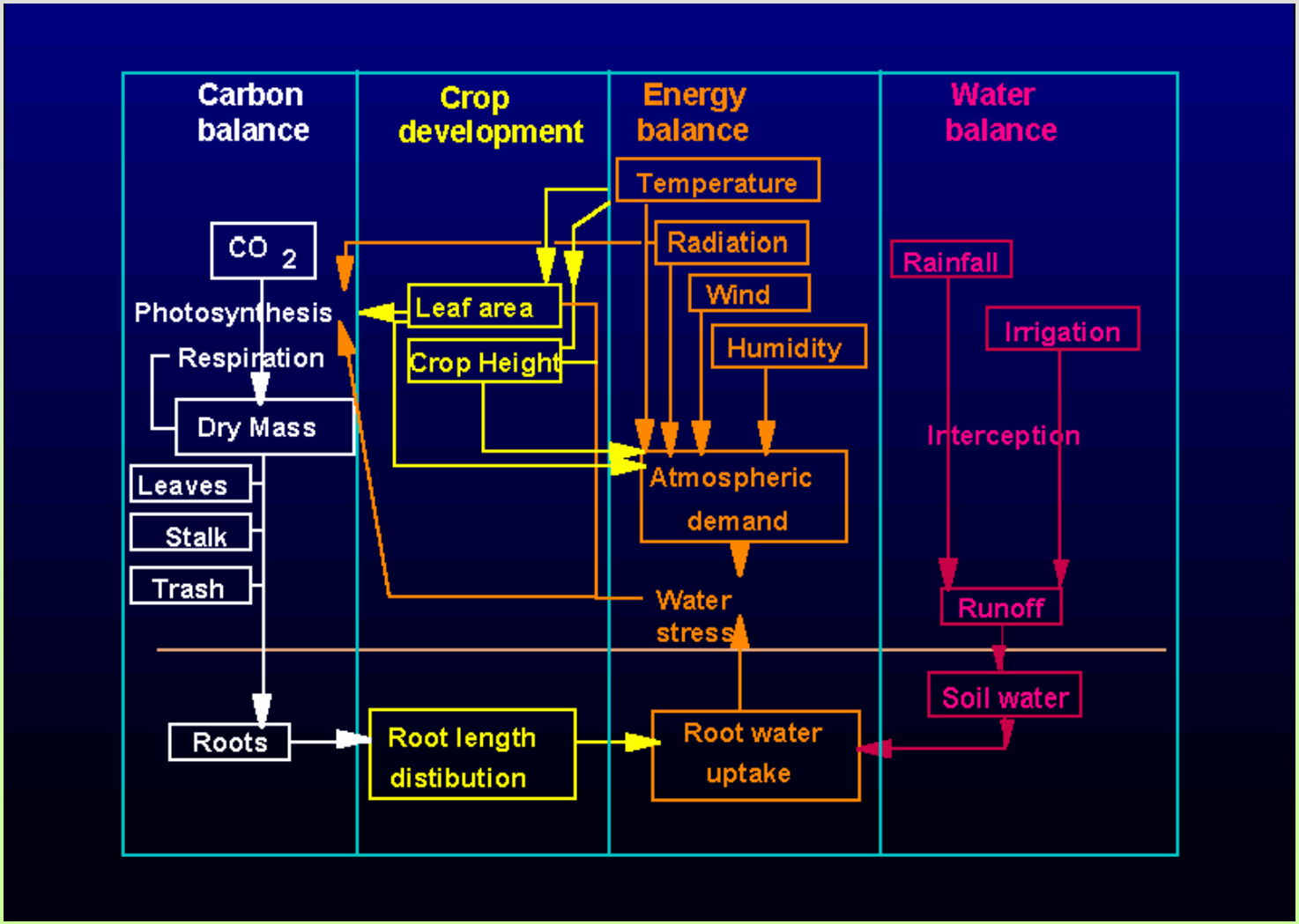
History

- Development started during the 70's
- Initially of Maize, Wheat, Sorghum
- Development on Sugarcane models began during early 80's
  - South Africa – CANEGRO
  - Australia – AusCane, Qcane, APSIM
  - Many others throughout the world
- Initially a research tool to compliment conventional experimentation
- Pressure to use models to assist agri-business
- Development continues today

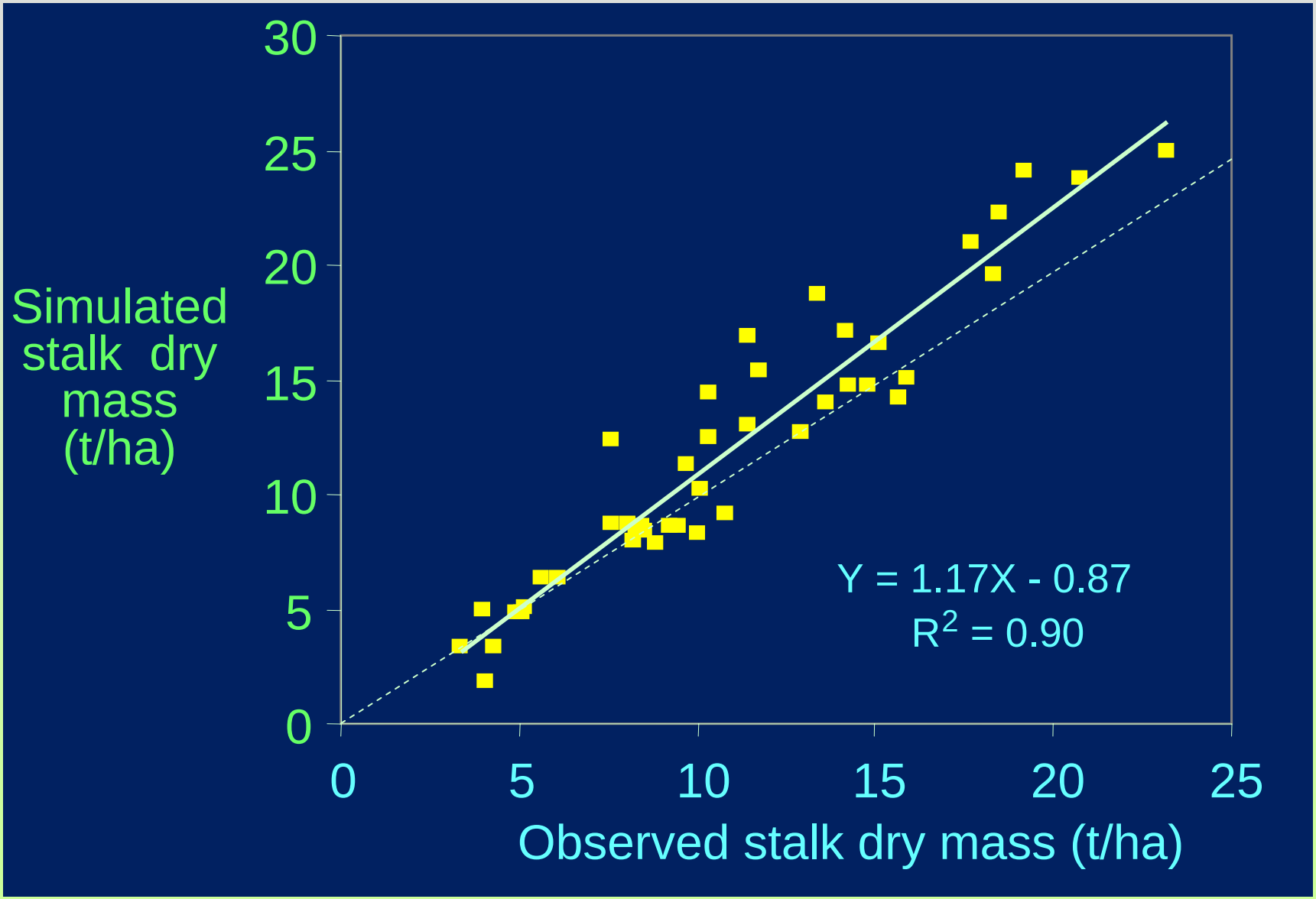
The CANEGRO crop model

- Developed primarily in South Africa
- International consortium – DSSAT
- Primarily climate-driven
- Features
  - Hesketh-McCree RUE-based Carbon Balance
  - Water balance – multi-layer single dimension model
  - Energy Balance – Sugarcane-specific Penman-Monteith
  - Mechanistic canopy development routine

CANEGRO - Conceptual Basis

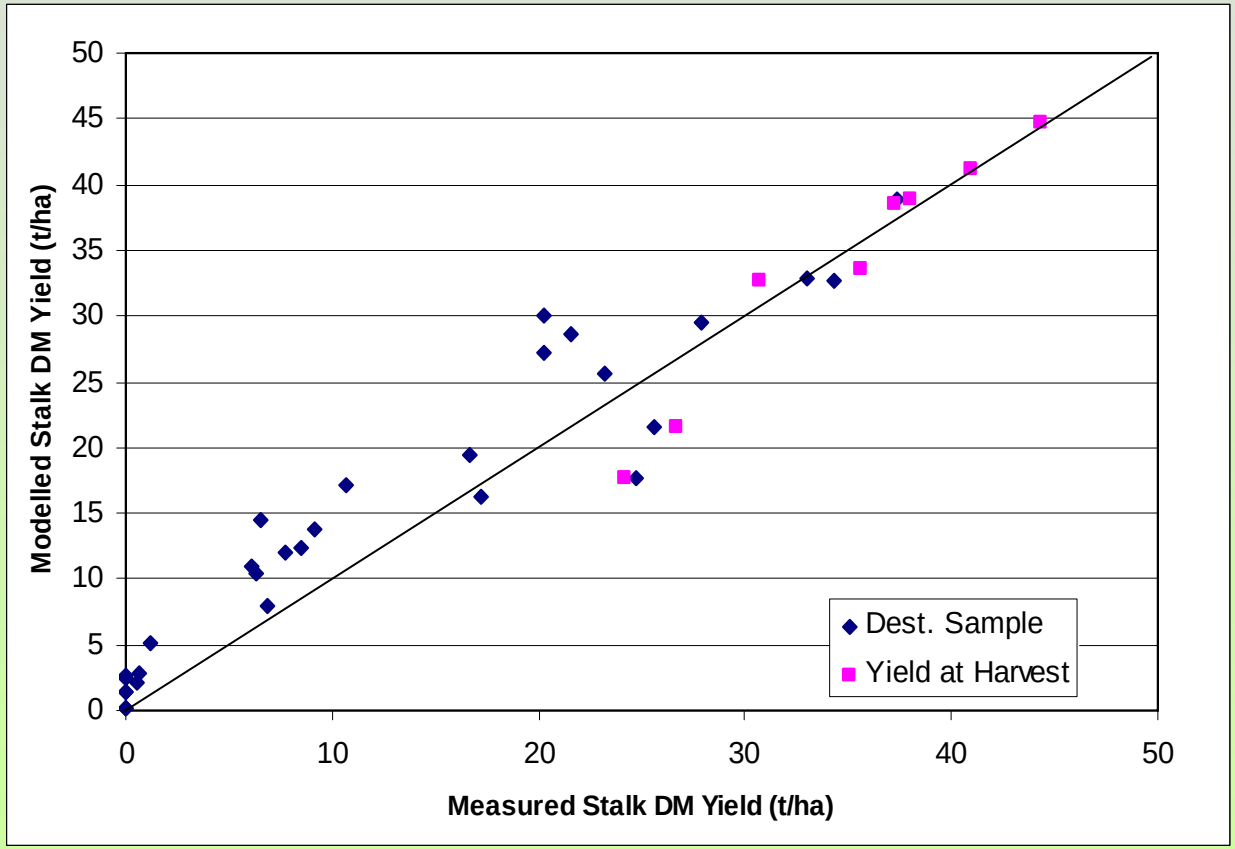


Model Validation – South Africa

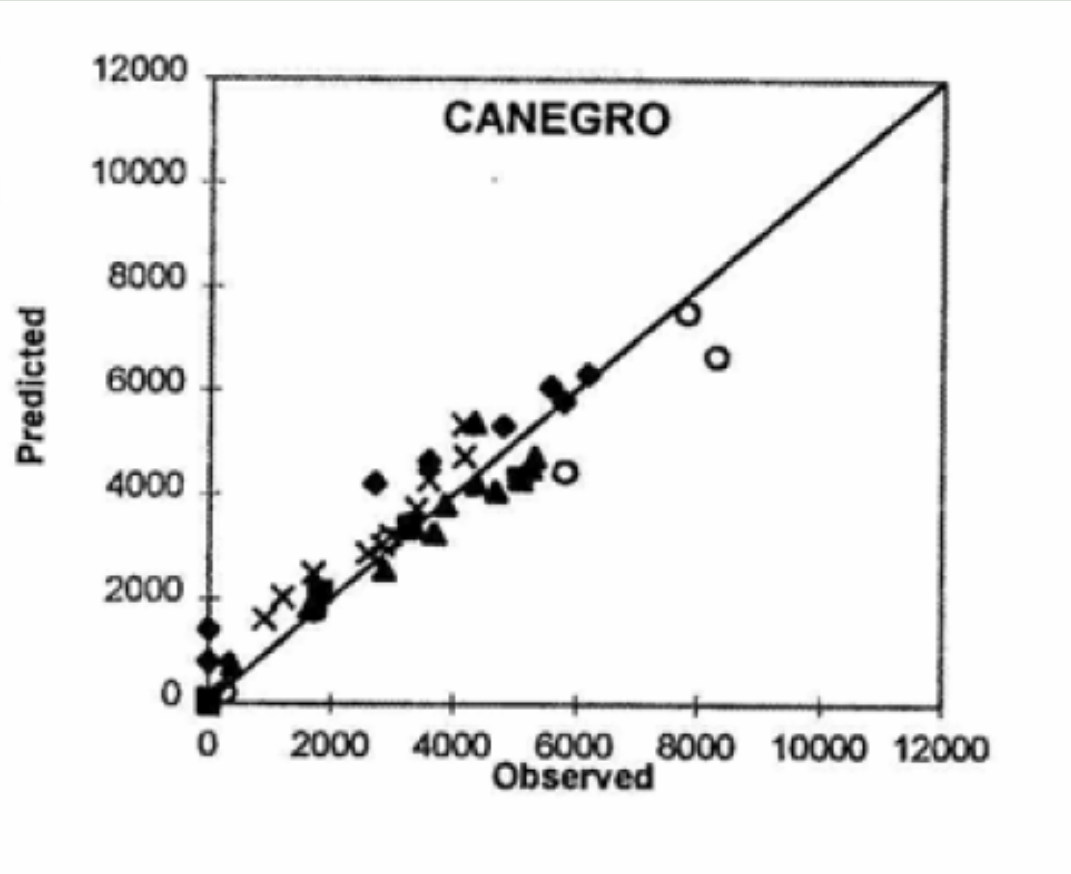


Model Validation - Swaziland

- Stress Trial – 4 levels of stress, 4 seasons
- Destructive sampling – 2 monthly intervals and
- Yield at Harvest



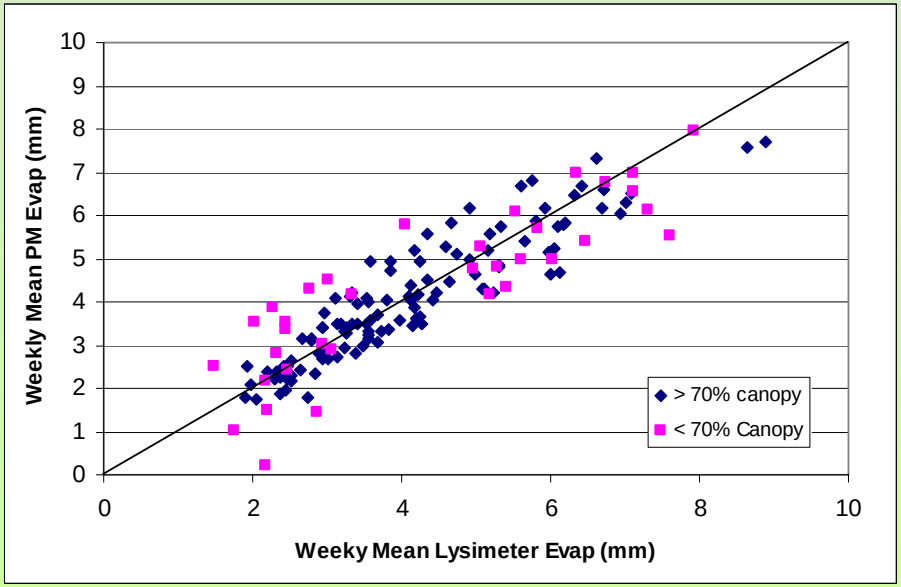
CANEGRO Validation - International

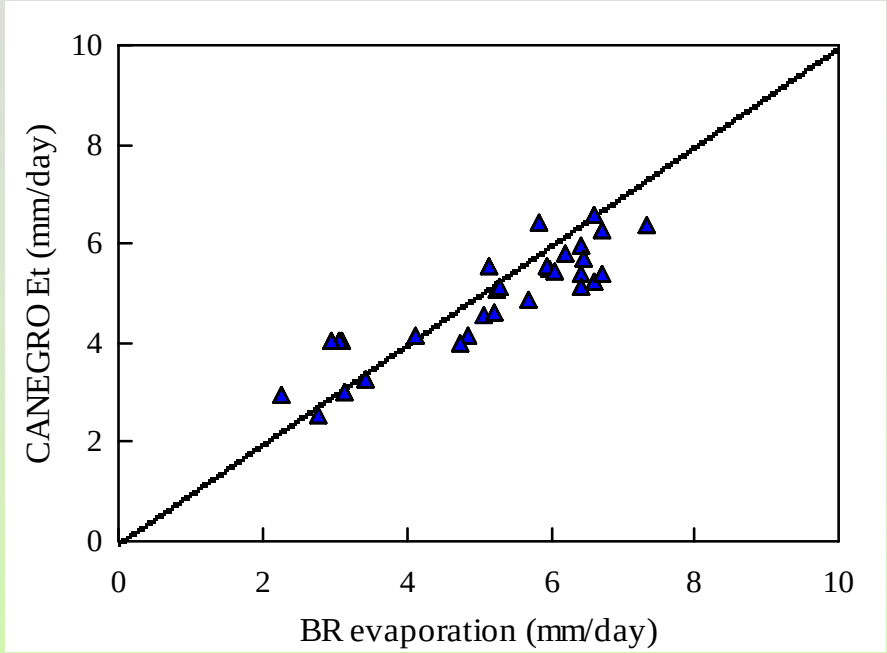


- 4 sites in Australia
- 1 site in Hawaii

CANEGRO Validation – Evapotranspiration Estimate

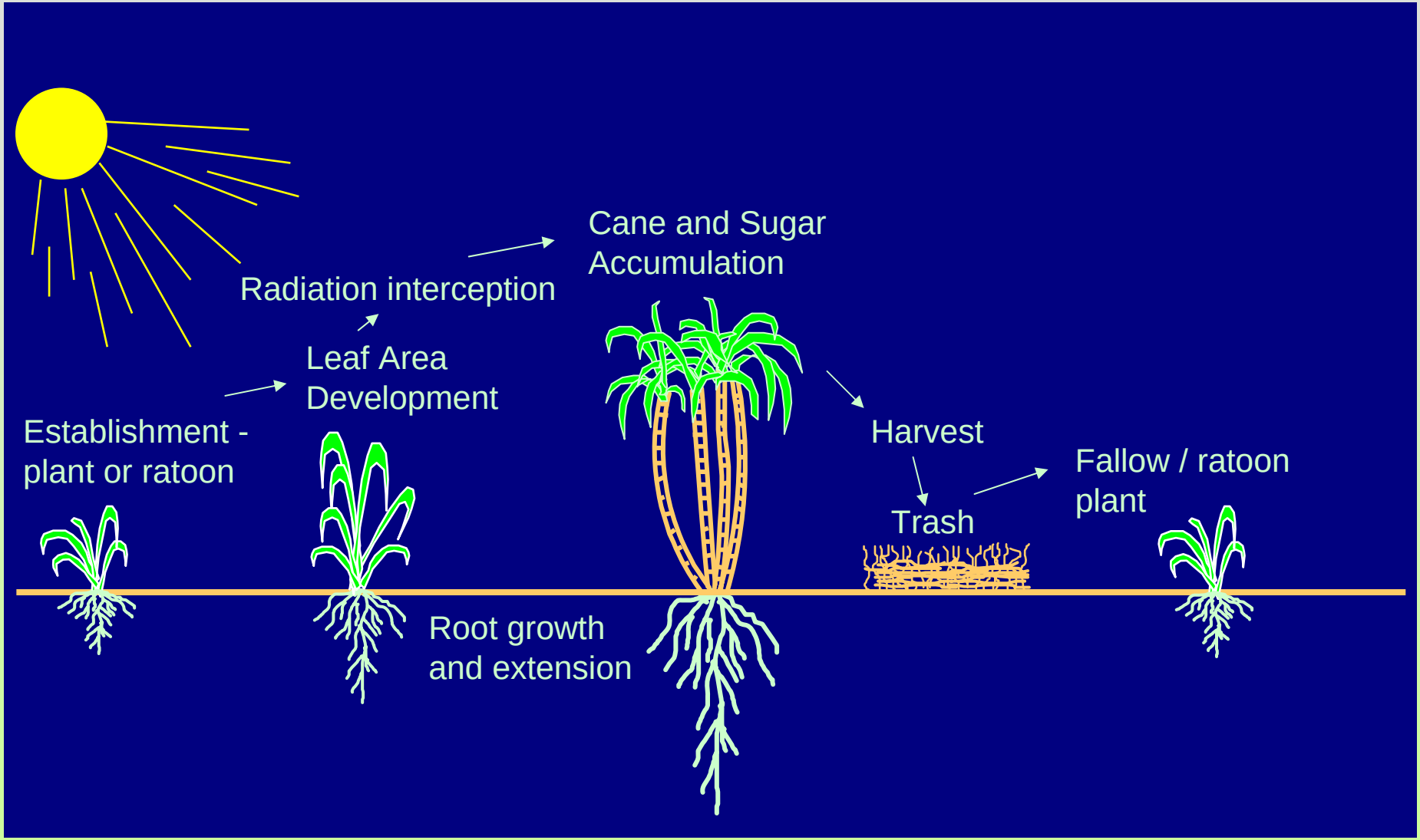
- Penman-Monteith sugarcane reference Et approach
- Original Validation – Three years Lysimeter data – Pongola, South Africa



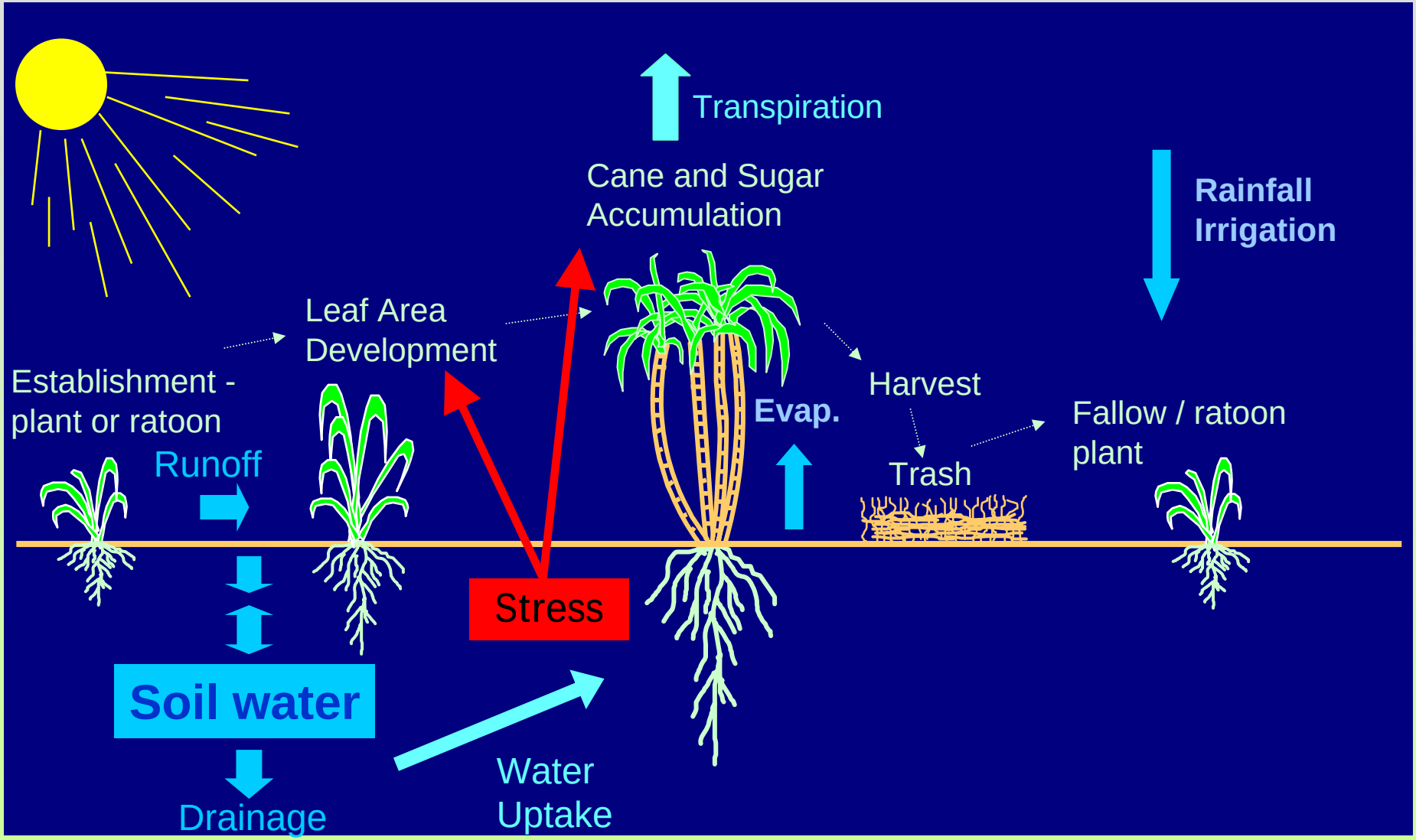


- Et Validation
- Bowen ratio Measurements, Swaziland

Potential Yield Calculation



Water Limited Yield Calculation

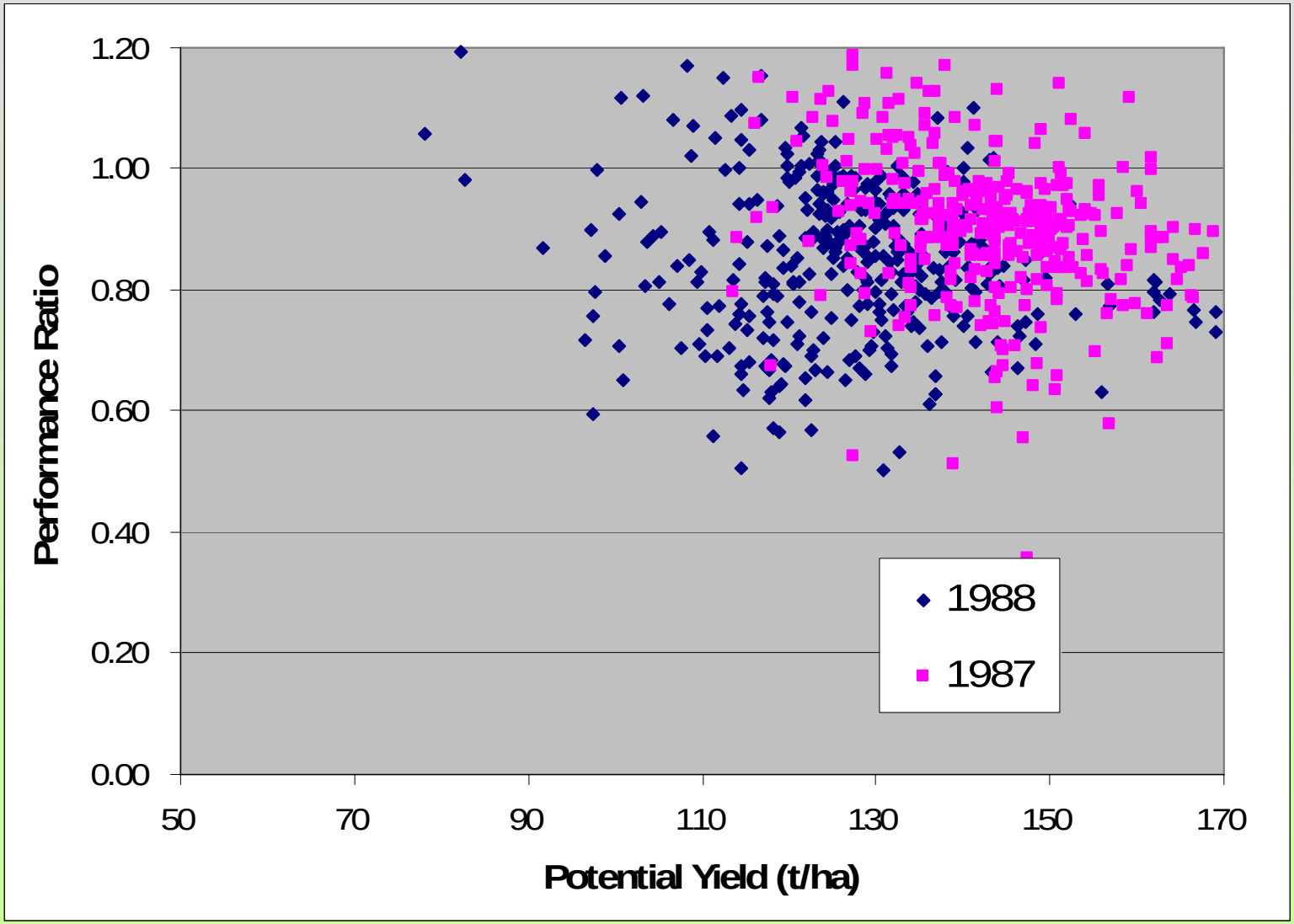


Evolution of a Benchmarking Tool Step 1 – Potential Yield

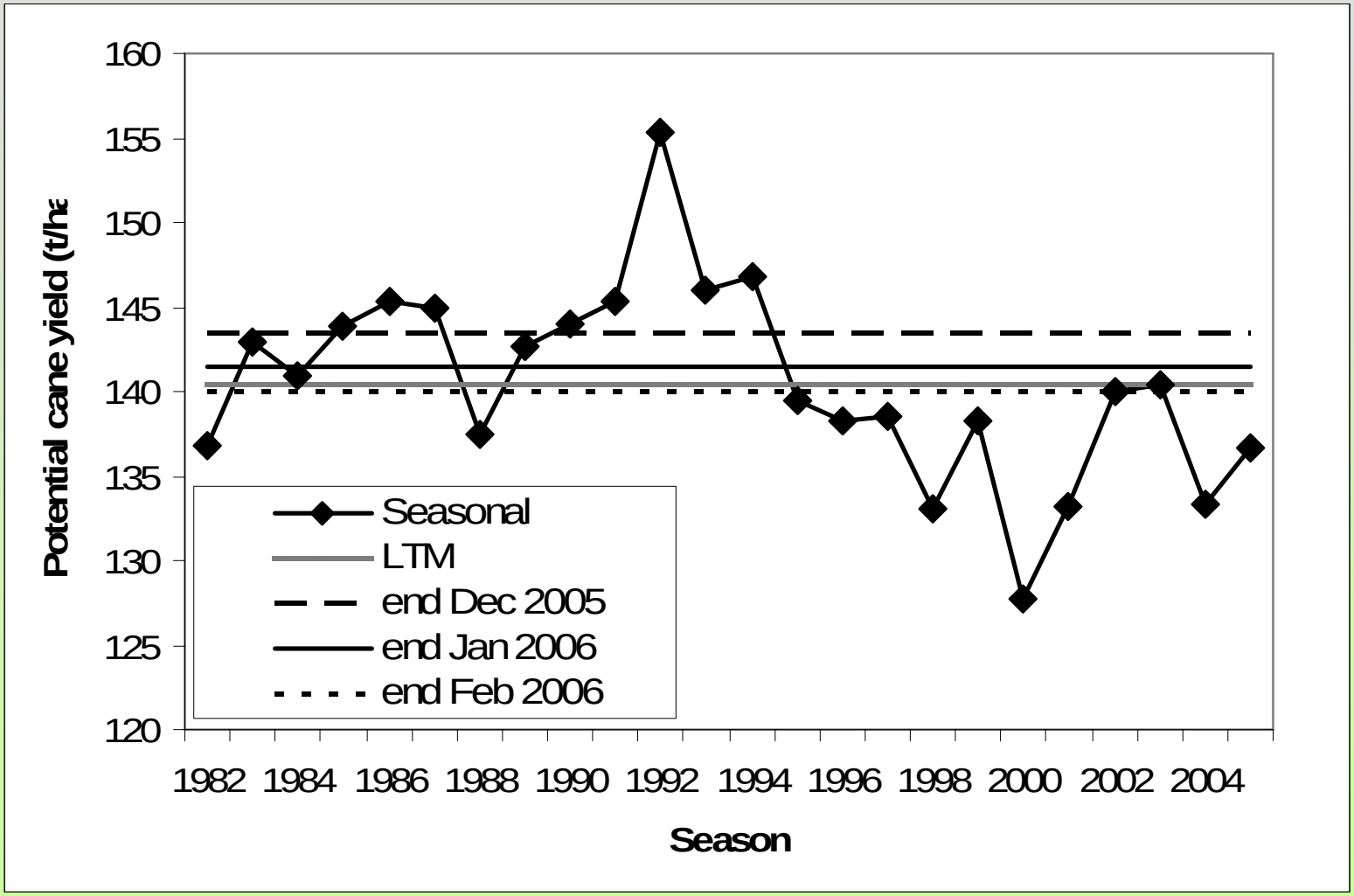
- Questions raised regarding performance at RSSC, Swaziland during the late 80's
- 1987/88 season avg yield = 130 t/ha
- 1988/89 season avg yield = 107 t/ha

- Why the big drop?

Season Potential and Performance



Potential Yield - Season Benchmarking

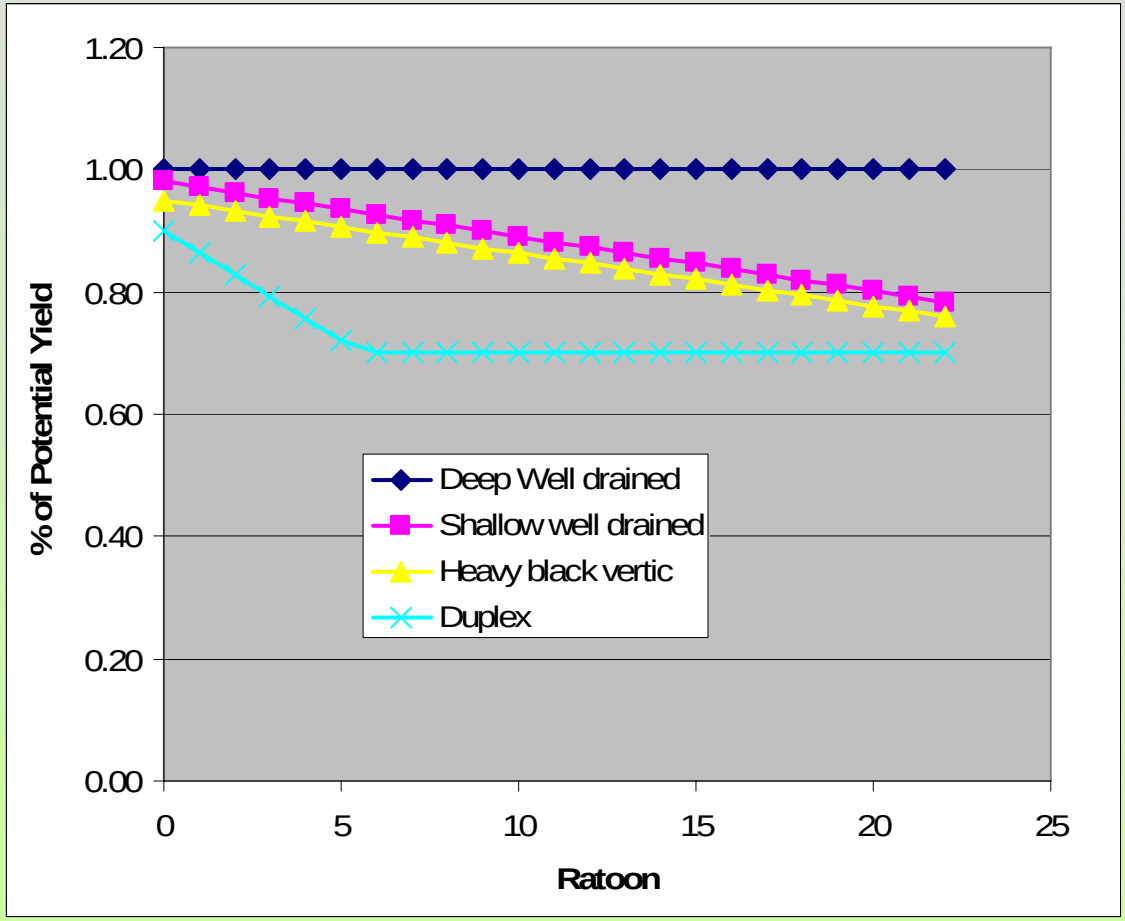


Evolution of a Benchmarking Tool Step 2 – Attainable Yield

- Questions regarding field performance comparisons raised
- Potential yield concept able to cope with seasonal variability
- Need to consider other agronomic constraints
- Led to development of Attainable Yield concept

Attainable Yield Concept

- Identified the soil/ratoon interaction as the most important agronomic consideration



Attainable Yield Concept

- Soil/Ratoon matrix combined with other agronomic factors in a simple multiplicative model of the form:
- AttYld = PotYld * Soil/Rat fac * Variety fac * Irrig fac
- Eg. Shallow well drained soil, 6th ratoon, NCo376, Drag-line irrigation system
- AttYld = 140 t/ha/an * 0.94 * 1.00 * 1.00 = 132 t/ha/an

Examples of model use in commercial operations – CanePro Cane Management Software

1. Harvest Planning and Yield Estimates

The Problem

- Large Estates
  - 3500 ha – 21000 ha
  - 100 – 1000 fields
  - Supplying 1 – 2 mills
- Complex harvest planning decisions
- Need for accurate estimates
  - Usually majority or only mill supply
  - Implications for season start and duration
- Need for in-season revision of estimate

Estate Practice – Prior to CanePro

- Estimate largely based on 5-year mean productivity
- Realise the effect of age and climate on yield but unsure how to incorporate into early estimates
- Rely on Section Managers subjective yield assessment
- Yield revisions 2 - 4 times per season

The Need

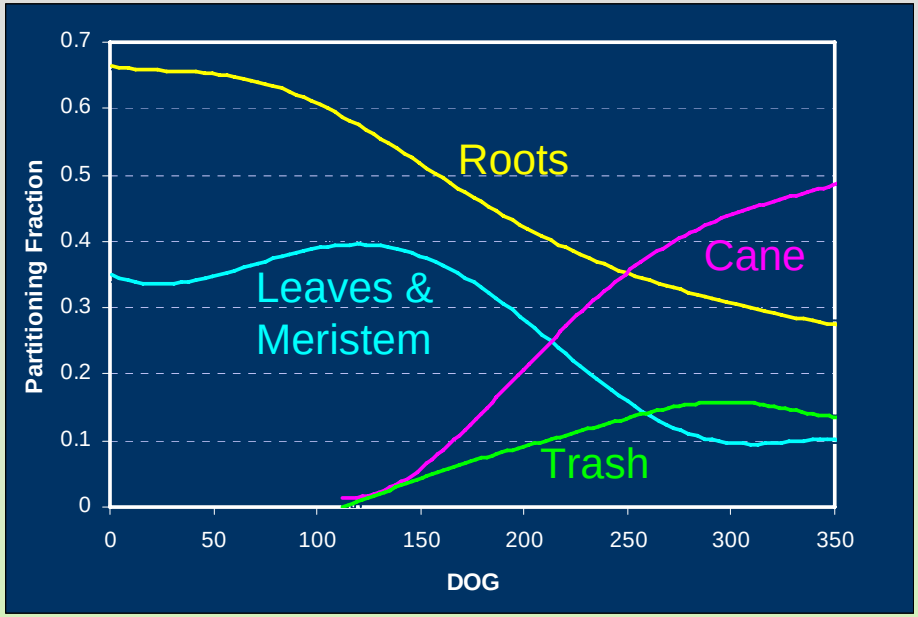
- Easy-to-use harvest planning tool which:
  - Is flexible
  - Integrates the effect of climate and age on yield
  - Provides real-time in-season revisions
  - Model inputs simple and easy to obtain

How?

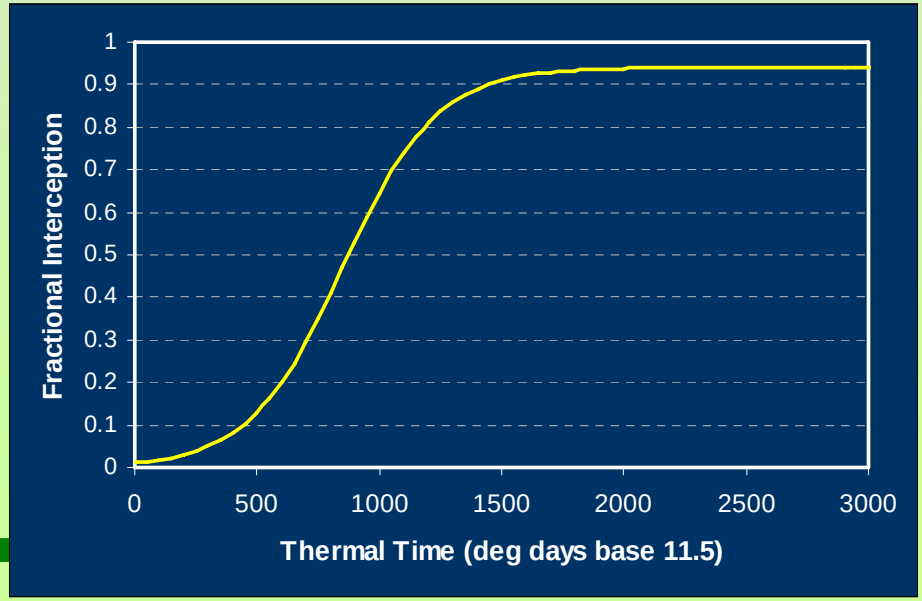
- Combine commercially available harvest planning engine with a simplified yield simulation model and performance ratio concept

Simplified Yield model

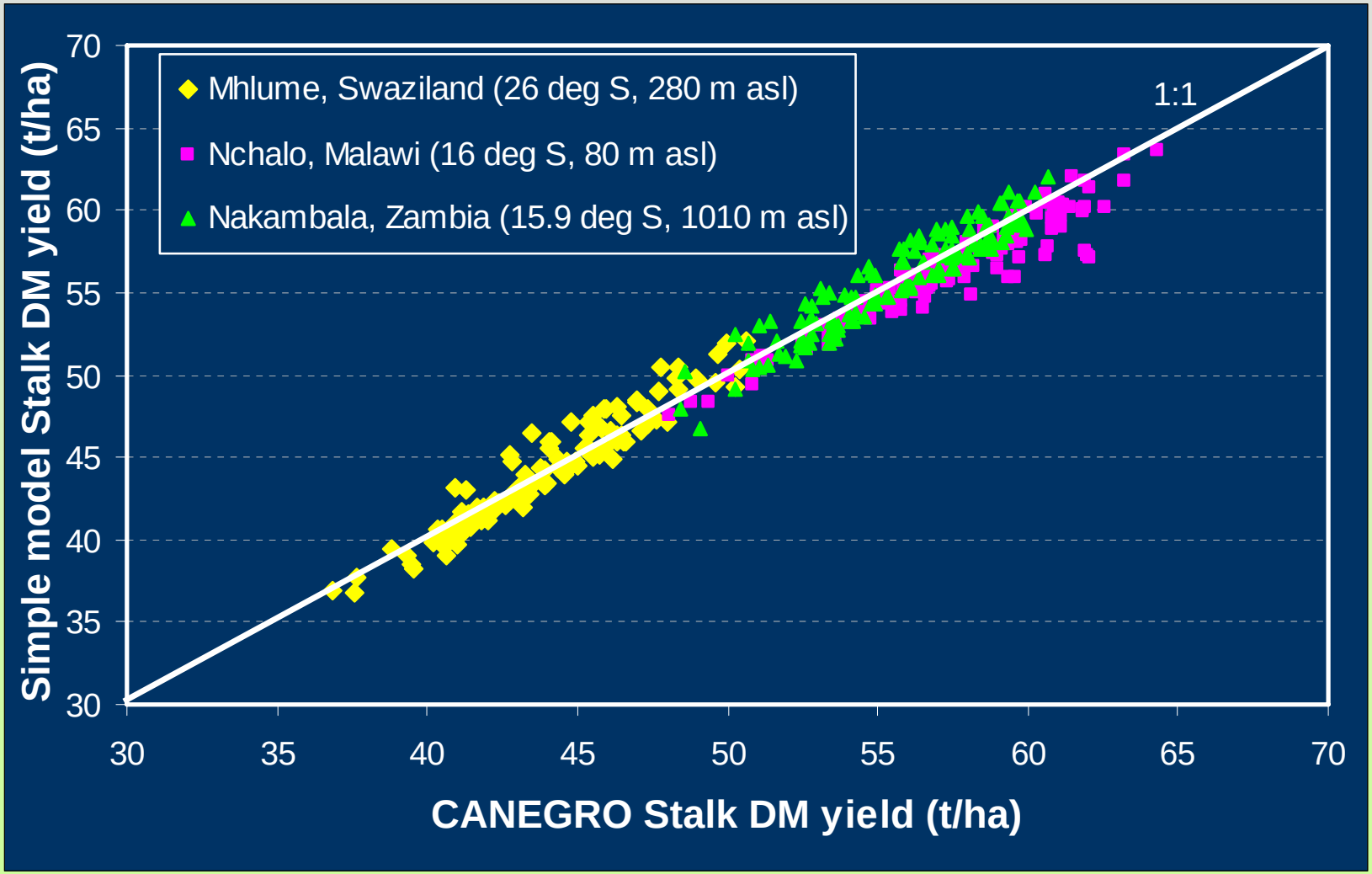
- Potential yield model developed using CANEGRO RUE model (McCree & Hesketh) and DM partitioning algorithms



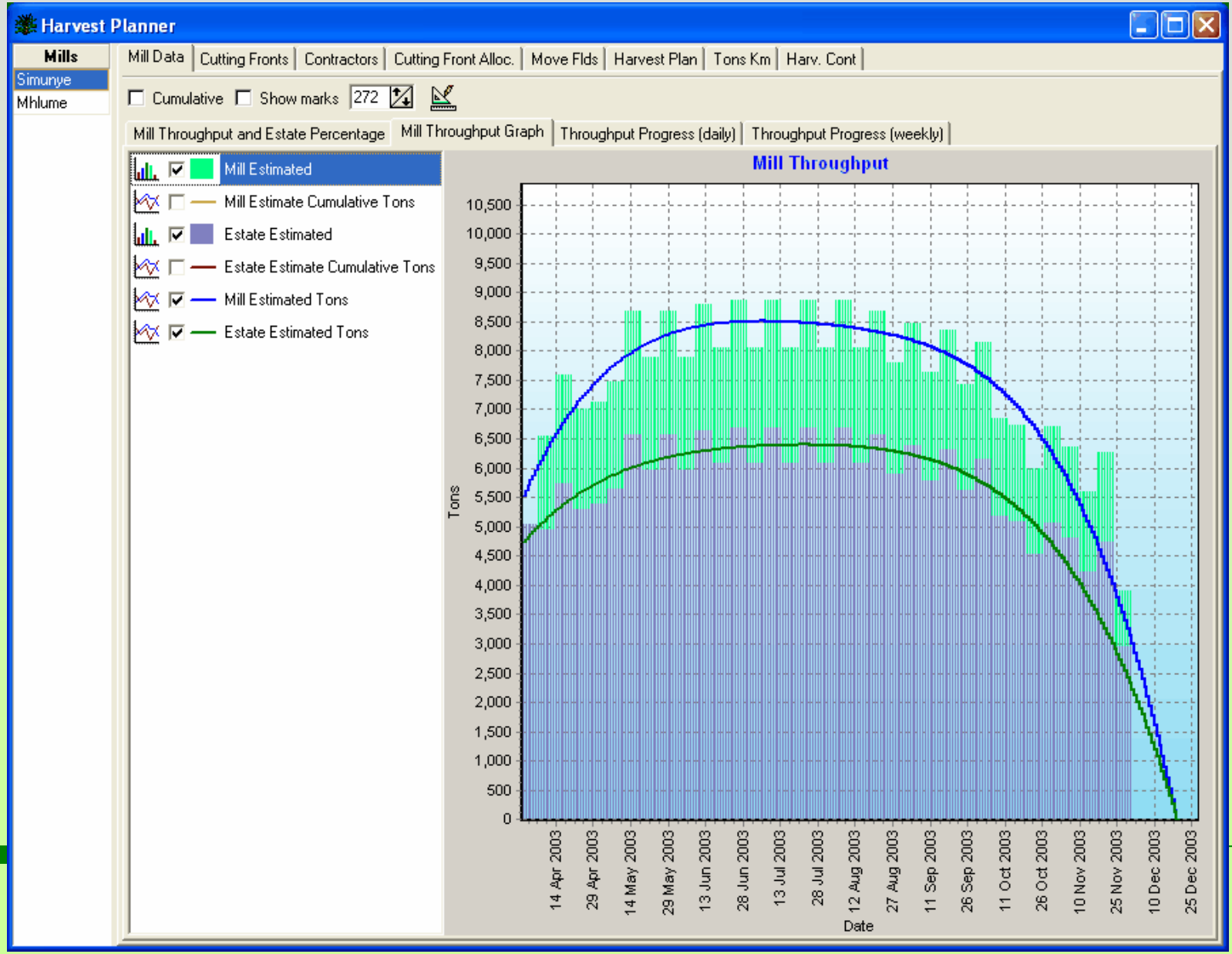
- Empirical temperature based radiation interception curve (base 11.5)



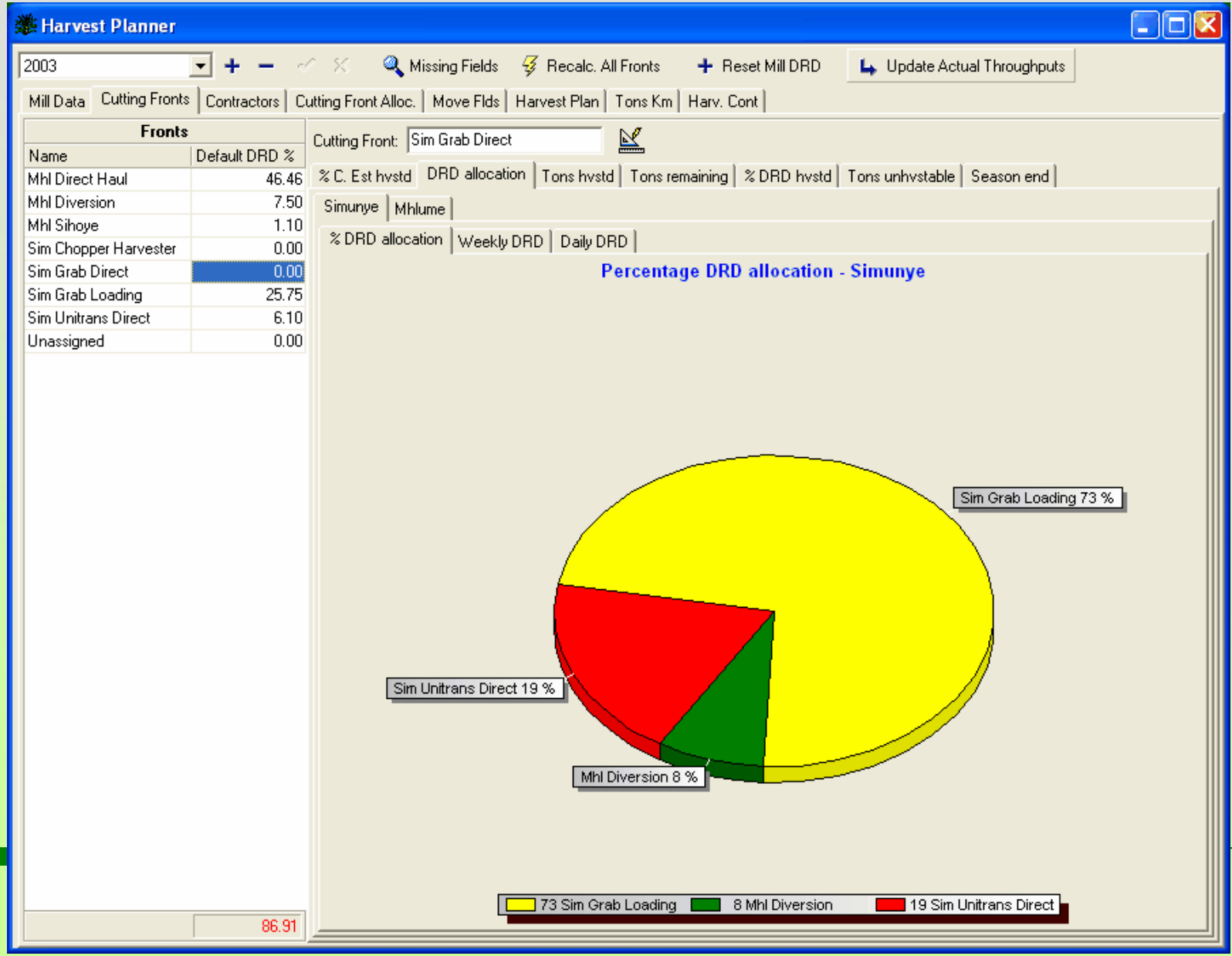
Model Validation



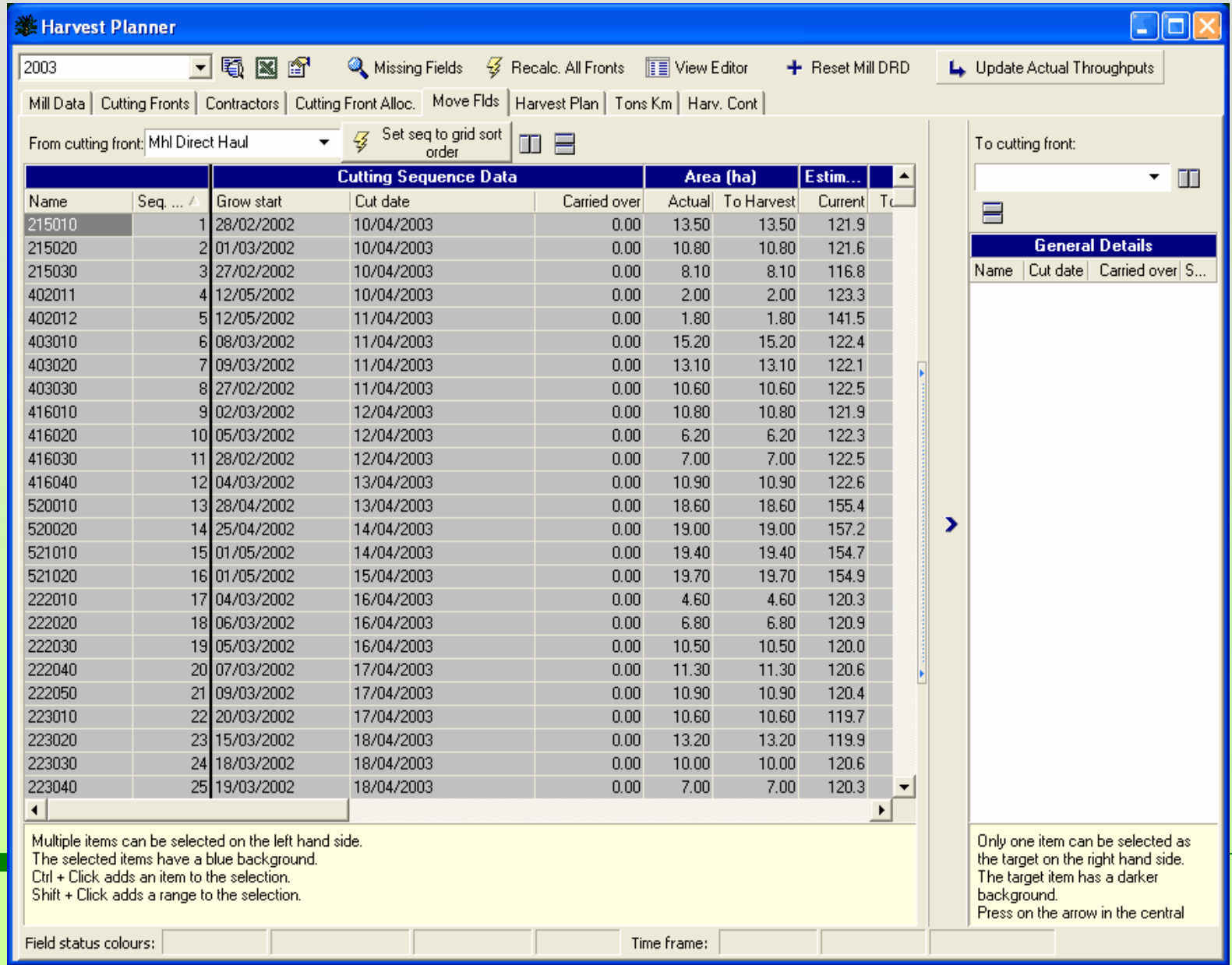
Step 1- Crush Programme



Step 2 – Cutting Fronts

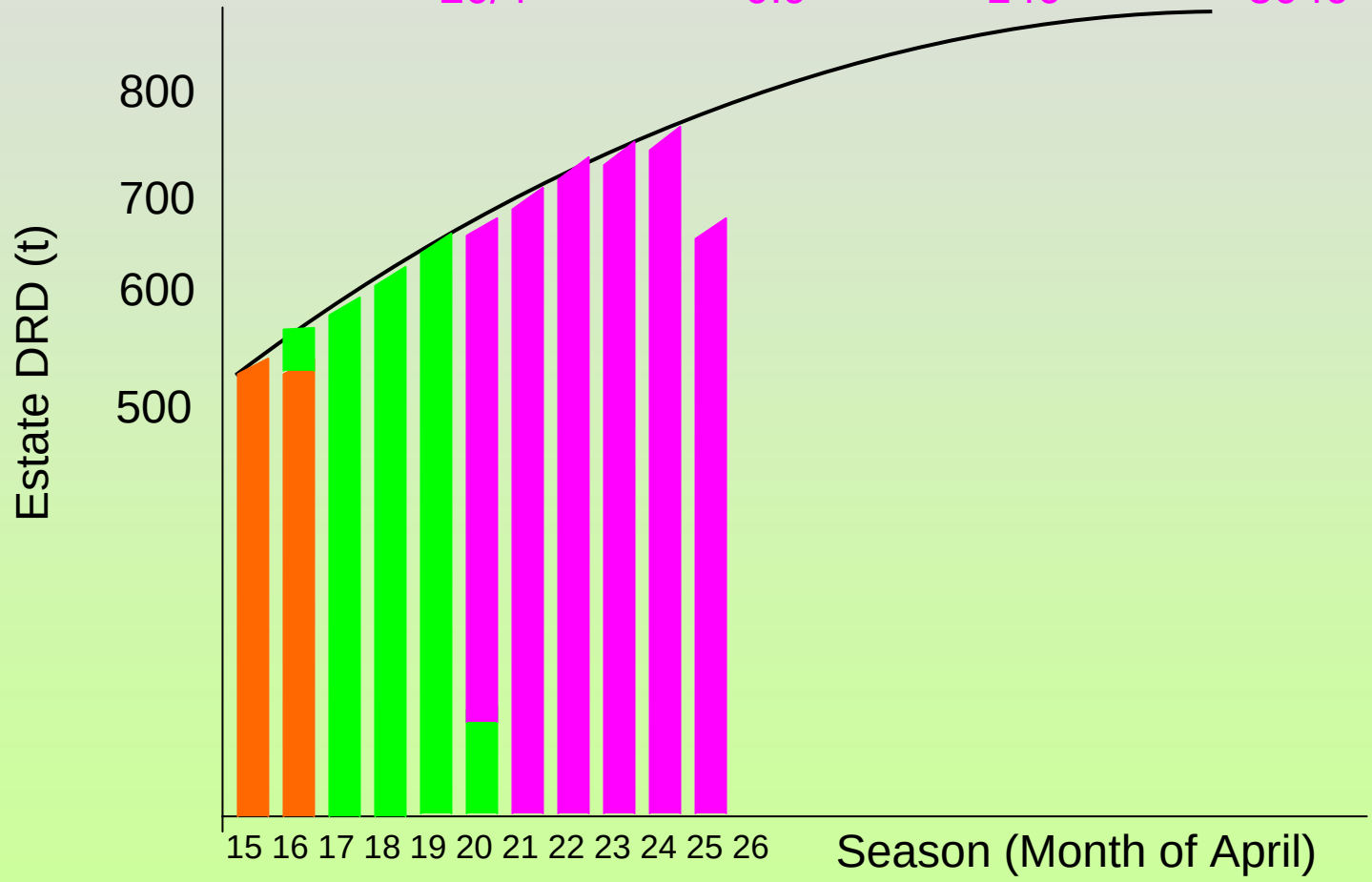


Step 3 – Field Harvest Order

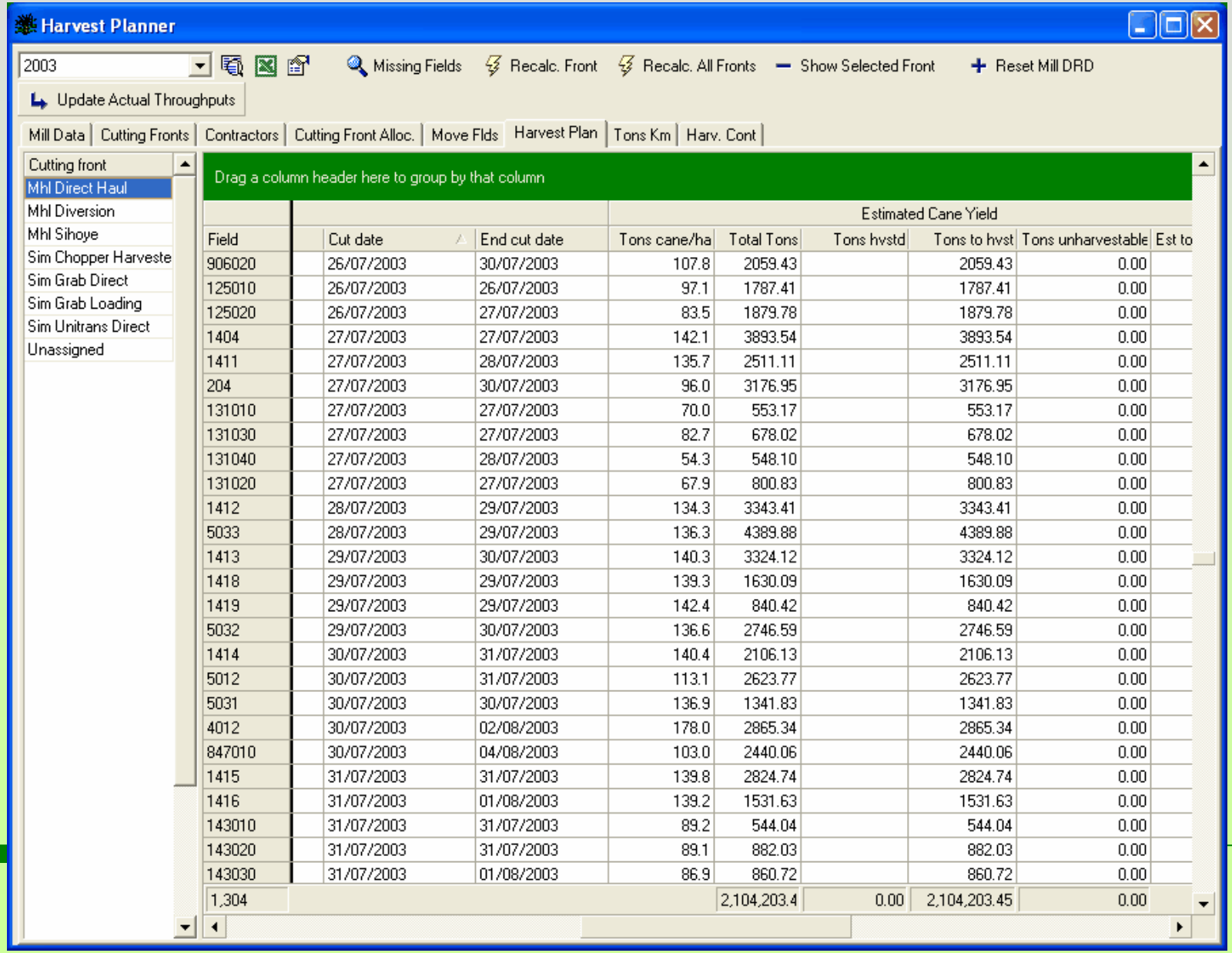


Step 4 – Harvest Plan

Order	Field	Size	Cut Start	Perf ratio	Potential yld	Yield (tons)	Cut End
1.	Field A – 10ha		15/4	0.7	140	980	16/4
2.	Field B – 20ha		16/4	0.8	140	2240	20/4
3.	Field C – 40ha		20/4	0.9	140	5040	25/4



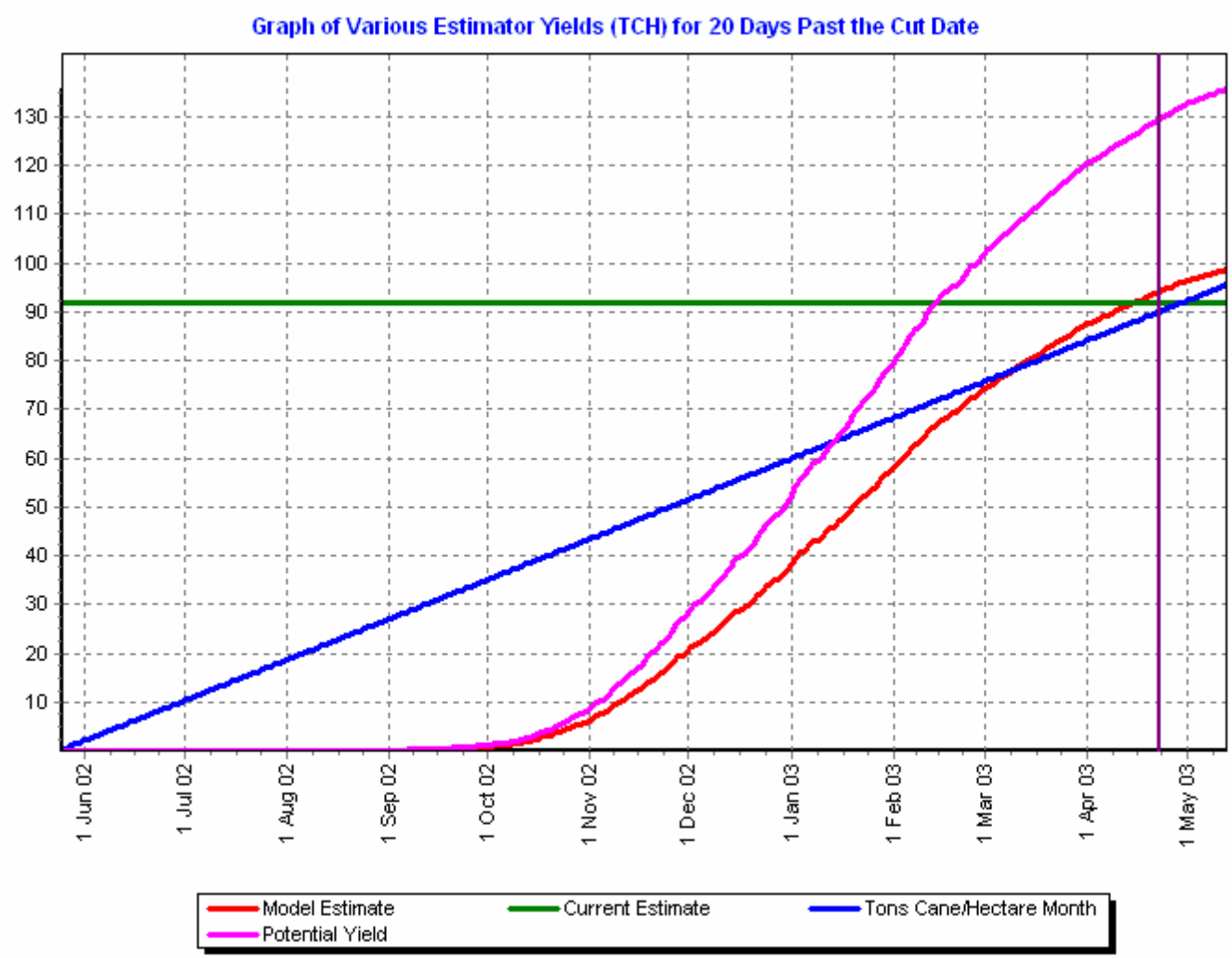
Step 4 (contd...) – Harvest Plan



Estimate Detail

Yield Data for Field: 315

- Current season Details	
Grow Start Date	25/05/2002
Cut Date	23/04/2003
Estimator Method	Current Estima
Area to Harvest	19.50
Orig. Area to Harvest	19.50
Tons/ha/mnth Est.	8.20
Current Estimate	91.87
Original Estimate	90.53
Official Estimate	0.00
Current Tons	1,791.47
Original Tons	1,765.43
TCHA	100.75
Ratoon	12
Cut Age	10.9
Perf. Ratio	
- Previous Seasons Yields (TCHA)	
2002	93.08
2001	93.62
2000	103.55
- Previous Seasons Ratoons	
2002	11
2001	10
2000	9
- Previous Seasons Cut Dates	
2002	24/05/2002
2001	30/05/2001
2000	10/06/2000
- Previous 3 Seasons Perf. Ratios	
2002	.68
2001	.69
2000	.81



Advantages

- Flexibility
  - Harvest date and estimate re-calculated if field harvest sequence changed
- Captures climate and age effects
- Live in-season
  - Harvest plan continually updated and estimate refreshed
- Better control of other operations linked to harvest date e.g. ripening
- What-if analysis w.r.t. season start and duration

Examples of model use in commercial operations – CanePro Cane Management Software

2. Performance Monitoring

Performance Monitoring

Harvested Fields for Season () and Locations (All)

Excel | Preview | Edit Graph | Filtering | Grouping | Swap Axis

Seasons (all): 1909, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989

All Section: 01, 02, 03, 04, 05, 06, 07, 08, 09, 10, 11, 12, 13, 14, 15

Variable (All) / Organisation

Variable	Organisation
Potential Yield (TCH)	139.7
Actual Yield (TCH)	98.1
Irrigation Limited Yield	96.0
Actual Tons	61,478.1
Age (mnth)	12.2
After Variety Rule (TC	140.3
After Soil/Ratoon Ru	136.0
After Irrigation Rule (T	136.0
After Season Rule (T	128.1
Actual as % of Potenl	70.2
Actual as % of Attain	76.6
Target Yield	115.3
Target Tons	72,227
Target Diff (Tons)	-10,749
Variance (%)	-14.9

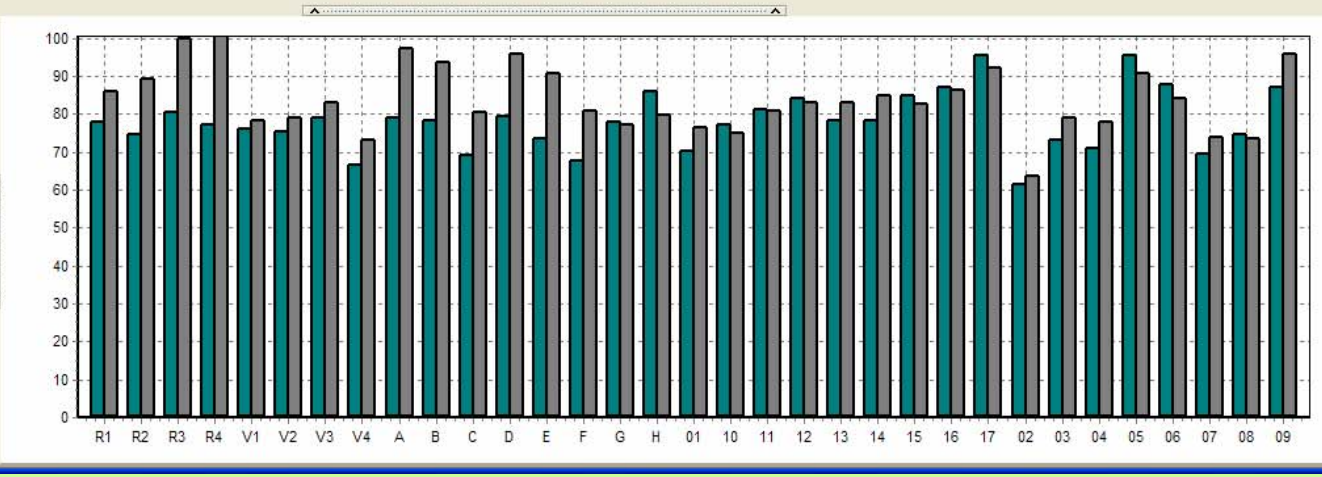
Department | Enterprise | Estate | Area | Section | CPU | Field

Drag a column header here to group by that column

Season	Location	Yield TCH					Rules TCH				Ratios		Target			
SeasonName	Location	Potential Yield (TCH)	Actual Yield (TCH)	Irrigation Limited Yield (...	Actual Tons	Age (mnth)	After Variety Rule (...	After Soil/Ratoon R...	After Irrigation Rule (...	After Season Rule (...	Actual as % of Potential	Actual as % of Attain...	Target Yield	Target Tons	Target Diff (Tons)	Variance (%)
2004	R1	122.0	95.1	51.2	55,701.1	12.2	121.4	112.3	112.3	110.7	77.9	85.9	99.6	58,366	-2,665	-4.6
2004	R2	124.8	93.0	54.5	58,302.3	12.5	124.0	107.7	107.7	104.1	74.6	89.4	93.7	58,703	-400	-0.7
2004	R3	119.6	96.4	60.4	51,847.6	12.6	118.6	98.5	98.5	96.7	80.6	99.7	87.0	46,790	5,057	10.8
2004	R4	121.4	93.6	52.1	49,659.2	12.5	120.3	95.3	95.3	93.0	77.1	100.6	83.7	44,441	5,218	11.7
2004	V1	122.3	93.0	60.9	55,457.5	12.2	122.0	118.2	121.8	118.8	76.1	78.3	106.9	63,721	-8,263	-13.0
2004	V2	121.3	91.6	67.2	46,767.0	12.0	121.2	116.4	120.0	116.1	75.5	78.9	104.5	53,361	-6,594	-12.4
2004	V3	109.7	86.6	53.4	42,928.4	10.5	109.0	103.5	106.0	104.3	79.0	83.1	93.8	46,518	-3,590	-7.7
2004	V4	136.6	91.0	64.9	17,344.6	13.3	136.0	129.4	129.4	124.7	66.7	73.0	112.2	21,373	-4,028	-18.8
2004	A	122.5	97.0	56.9	57,228.4	12.6	121.3	102.5	102.5	99.8	79.1	97.1	89.9	53,025	4,204	7.9
2004	B	129.0	101.1	57.6	43,265.5	12.8	128.3	111.5	111.5	108.1	78.4	93.6	97.3	41,616	1,649	4.0
2004	C	115.4	79.8	59.6	39,172.3	12.3	114.6	100.9	100.9	99.4	69.1	80.3	89.5	43,917	-4,745	-10.8
2004	D	129.2	102.3	63.1	55,894.4	13.0	127.9	109.4	109.6	106.6	79.2	96.0	96.0	52,423	3,471	6.6
2004	E	127.1	93.3	56.3	54,242.8	12.8	126.1	105.8	105.8	102.9	73.4	90.6	92.7	53,868	374	0.7
2004	F	119.9	81.3	55.2	56,755.6	12.2	119.5	103.8	103.8	100.8	67.8	80.7	90.7	63,334	-6,579	-10.4
2004	G	122.8	95.6	58.4	53,401.6	11.6	122.5	120.4	127.9	123.7	77.9	77.3	111.3	62,174	-8,772	-14.1

Individual Amounts

- [ ] Potential Yield (TCH)
- [ ] Actual Yield (TCH)
- [ ] Irrigation Limited Yield (TCH
- [ ] Actual Tons
- [ ] Age (mnth)
- [ ] After Variety Rule (TCH)
- [ ] After Soil/Ratoon Rules (T
- [ ] After Irrigation Rule (TCH)
- [ ] After Season Rule (TCH)
- [x] Actual as % of Potential
- [x] Actual as % of Attainable
- [ ] Target Yield
- [ ] Target Tons



Advantages

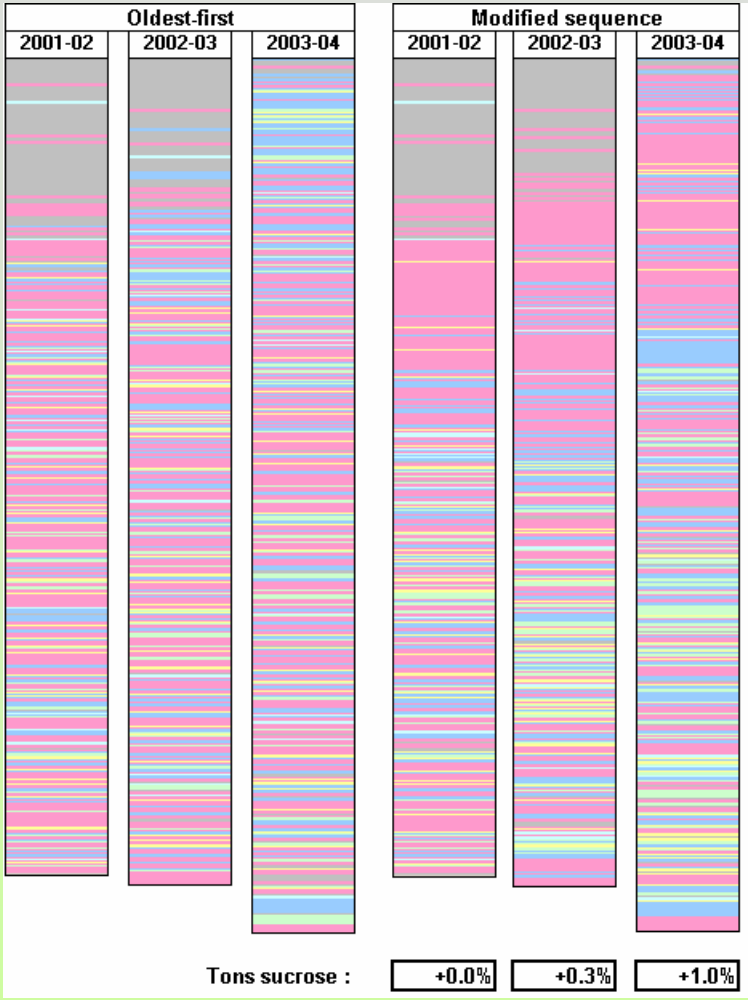
- Allows for comparisons between/within season
- Allows benchmarking between estates
- Allows benchmarking between different environments/countries
- Used to assess manager performance
- Crucial part of replant planning decisions

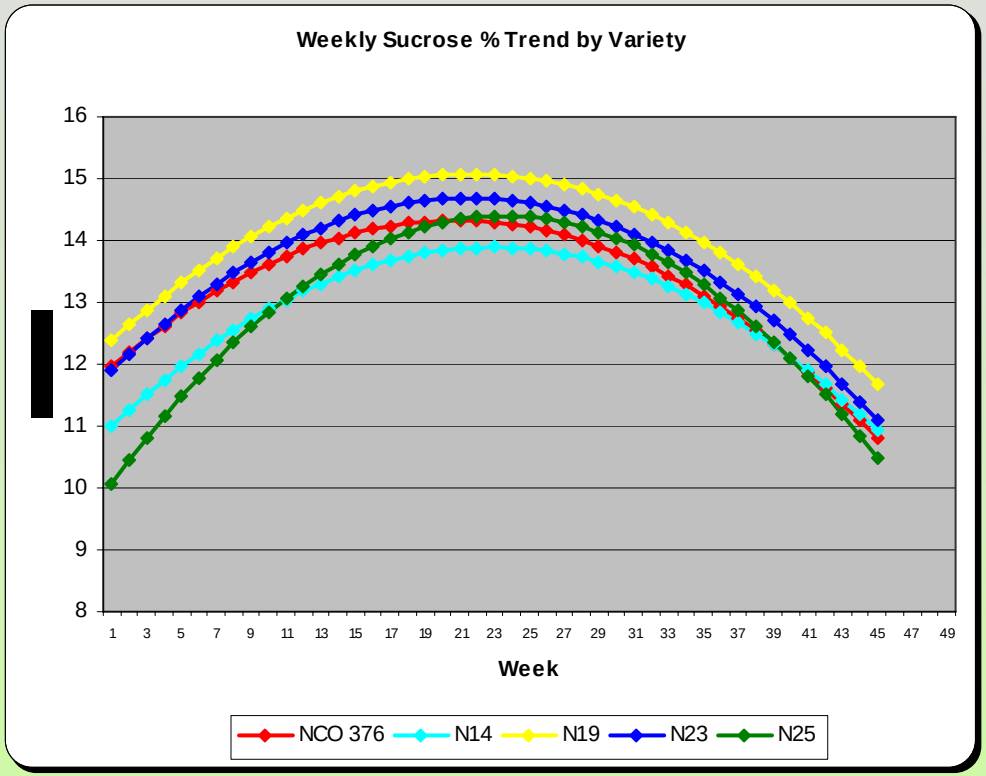
Examples of model use in commercial operations – CanePro Cane Management Software

3. Harvest Sequencing

Harvest Planner Developments

- Optimise harvest sequence using knowledge of sugarcane physiology
  - Seasonal growth characteristics
  - Seasonal cane moisture profile
  - Seasonal cane sucrose curve


Oldest-first
2001-02
2002-03
2003-04
Modified sequence
2001-02
2002-03
2003-04
Tons sucrose :
+0.0%
+0.3%
+1.0%


Weekly Sucrose % Trend by Variety
16
15
14
13
12
11
10
9
8
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
Week
NCO 376
N14
N19
N23
N25

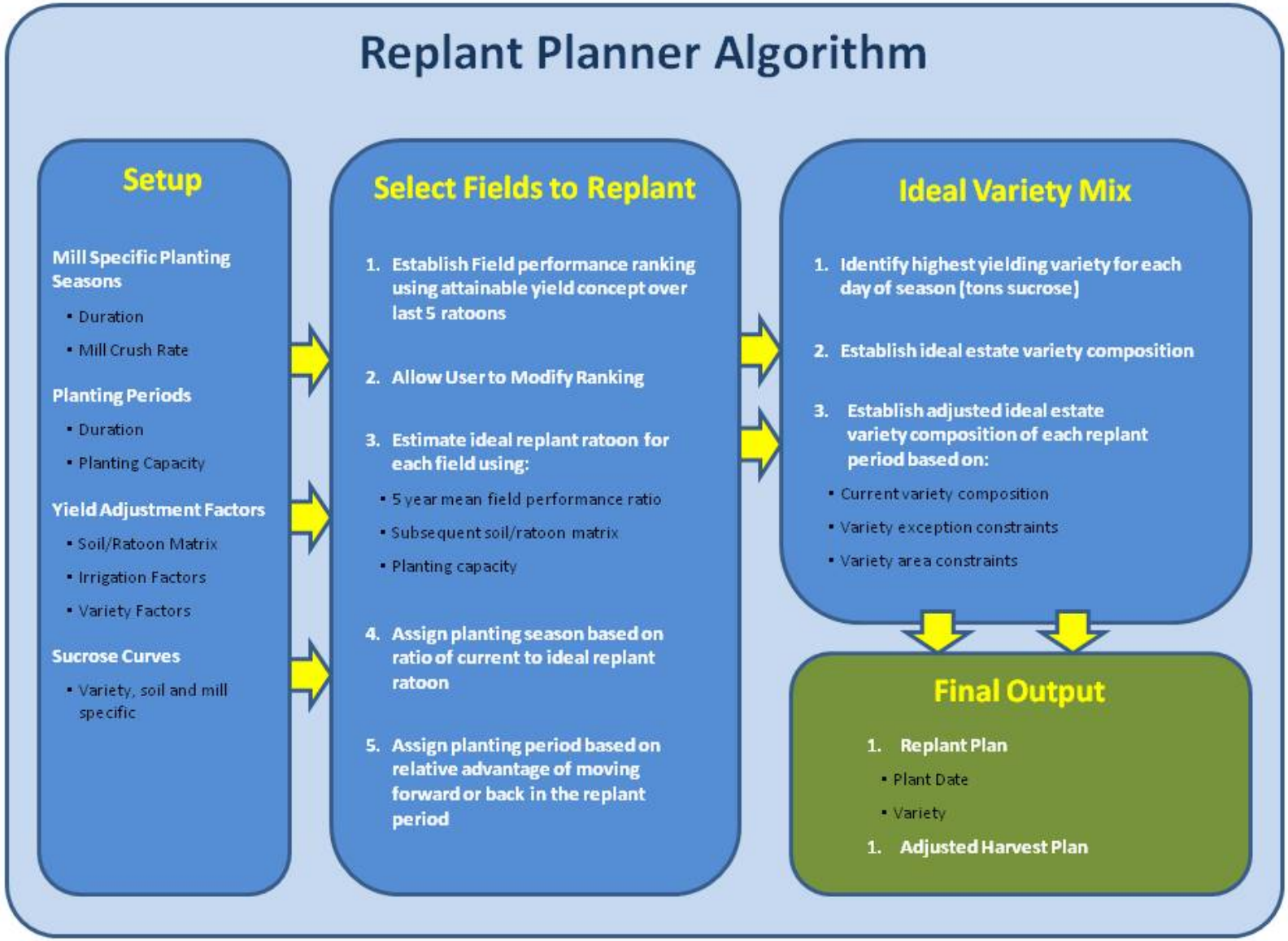
Quickly realised that to optimise harvest sequence one cannot ignore replanting and the need to accommodate the movement of fields to be replanted

Examples of model use in commercial operations – CanePro Cane Management Software

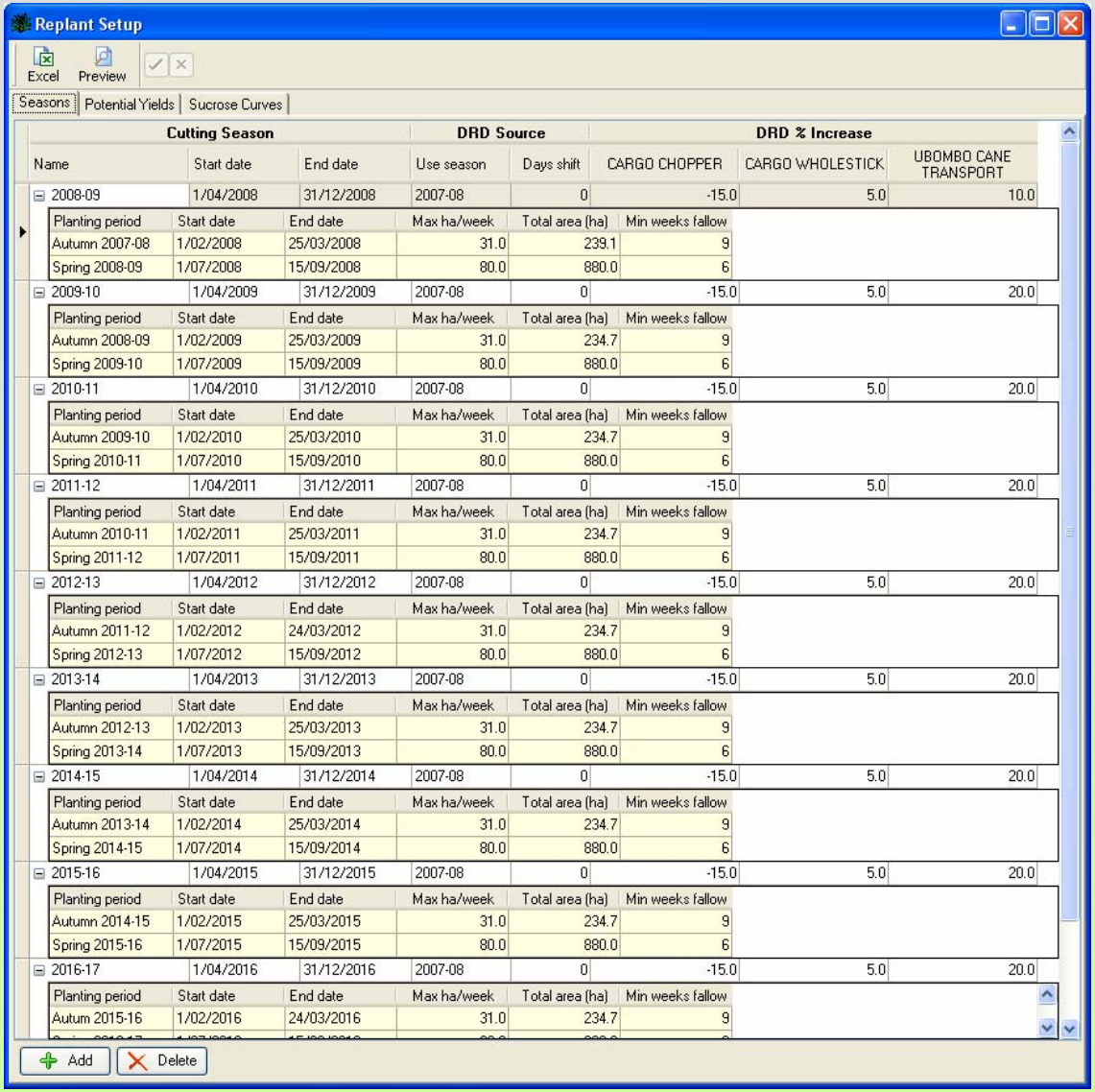
4. Replant Planning

Replant Planning Concepts

- Identify fields to be replanted and when over a selected number of cutting seasons.
- Identify which varieties should be used to replant each field to obtain an ideal variety mix.
- Integrate a knowledge of replant dates into the harvest plan to optimise field sequencing over the chosen cutting seasons.


Replant Planner Algorithm
Setup
Mill Specific Planting Seasons
• Duration
• Mill Crush Rate
Planting Periods
• Duration
• Planting Capacity
Yield Adjustment Factors
• Soil/Ratoon Matrix
• Irrigation Factors
• Variety Factors
Sucrose Curves
• Variety, soil and mill specific
Select Fields to Replant
1. Establish Field performance ranking using attainable yield concept over last 5 ratoons
2. Allow User to Modify Ranking
3. Estimate ideal replant ratoon for each field using:
• 5 year mean field performance ratio
• Subsequent soil/ratoon matrix
• Planting capacity
4. Assign planting season based on ratio of current to ideal replant ratoon
5. Assign planting period based on relative advantage of moving forward or back in the replant period
Ideal Variety Mix
1. Identify highest yielding variety for each day of season (tons sucrose)
2. Establish ideal estate variety composition
3. Establish adjusted ideal estate variety composition of each replant period based on:
• Current variety composition
• Variety exception constraints
• Variety area constraints
Final Output
1. Replant Plan
• Plant Date
• Variety
1. Adjusted Harvest Plan

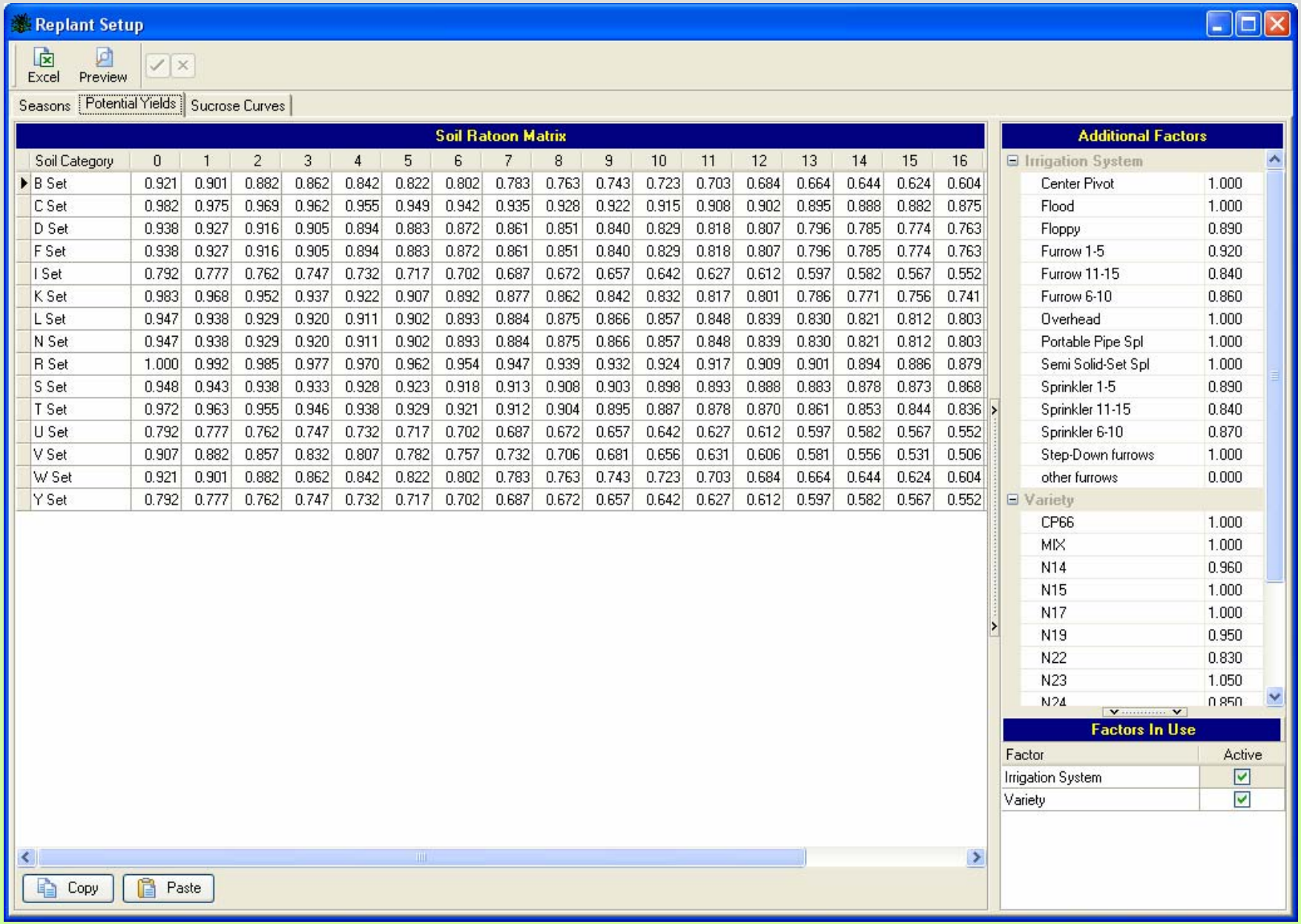
Step 1- Setup - Seasons



Cutting Season			DRD Source		DRD % Increase		
Name	Start date	End date	Use season	Days shift	CARGO CHOPPER	CARGO WHOLESTICK	UBOMBO CANE TRANSPORT
2008-09	1/04/2008	31/12/2008	2007-08	0	-15.0	5.0	10.0
2009-10	1/04/2009	31/12/2009	2007-08	0	-15.0	5.0	20.0
2010-11	1/04/2010	31/12/2010	2007-08	0	-15.0	5.0	20.0
2011-12	1/04/2011	31/12/2011	2007-08	0	-15.0	5.0	20.0
2012-13	1/04/2012	31/12/2012	2007-08	0	-15.0	5.0	20.0
2013-14	1/04/2013	31/12/2013	2007-08	0	-15.0	5.0	20.0
2014-15	1/04/2014	31/12/2014	2007-08	0	-15.0	5.0	20.0
2015-16	1/04/2015	31/12/2015	2007-08	0	-15.0	5.0	20.0
2016-17	1/04/2016	31/12/2016	2007-08	0	-15.0	5.0	20.0

Planting period	Start date	End date	Max ha/week	Total area (ha)	Min weeks fallow
Autumn 2007-08	1/02/2008	25/03/2008	31.0	239.1	9
Spring 2008-09	1/07/2008	15/09/2008	80.0	880.0	6
Autumn 2008-09	1/02/2009	25/03/2009	31.0	234.7	9
Spring 2009-10	1/07/2009	15/09/2009	80.0	880.0	6
Autumn 2009-10	1/02/2010	25/03/2010	31.0	234.7	9
Spring 2010-11	1/07/2010	15/09/2010	80.0	880.0	6
Autumn 2010-11	1/02/2011	25/03/2011	31.0	234.7	9
Spring 2011-12	1/07/2011	15/09/2011	80.0	880.0	6
Autumn 2011-12	1/02/2012	24/03/2012	31.0	234.7	9
Spring 2012-13	1/07/2012	15/09/2012	80.0	880.0	6
Autumn 2012-13	1/02/2013	25/03/2013	31.0	234.7	9
Spring 2013-14	1/07/2013	15/09/2013	80.0	880.0	6
Autumn 2013-14	1/02/2014	25/03/2014	31.0	234.7	9
Spring 2014-15	1/07/2014	15/09/2014	80.0	880.0	6
Autumn 2014-15	1/02/2015	25/03/2015	31.0	234.7	9
Spring 2015-16	1/07/2015	15/09/2015	80.0	880.0	6
Autum 2015-16	1/02/2016	24/03/2016	31.0	234.7	9

Step 1- Setup – Soil / Ratoon matrix



Step 1- Setup – Variety Quality Curves

Replant Setup

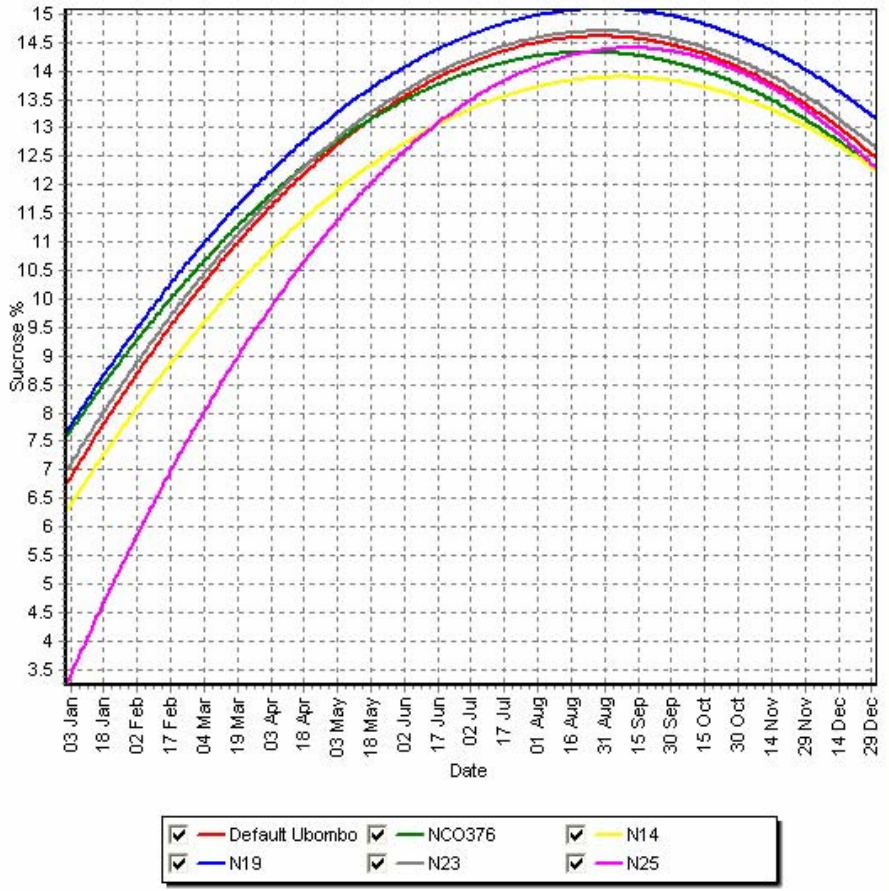
Excel | Preview

Seasons | Potential Yields | Sucrose Curves

Name	Polynomial Coefficients			Applies To		
	Constant	Linear	Quadratic	Mill	Variety	Soils
Default Ubombo	6.672	6.597E-2	-1.372E-4	Ubombo	All varieties	All soils
NCO376	7.511	5.784E-2	-1.228E-4	Ubombo	NCO376	All soils
N14	6.198	6.156E-2	-1.232E-4	Ubombo	N14	All soils
N19	7.586	6.193E-2	-1.279E-4	Ubombo	N19	All soils
N23	6.907	6.455E-2	-1.338E-4	Ubombo	N23	All soils
N25	3.140	8.831E-2	-1.732E-4	Ubombo	N25	All soils

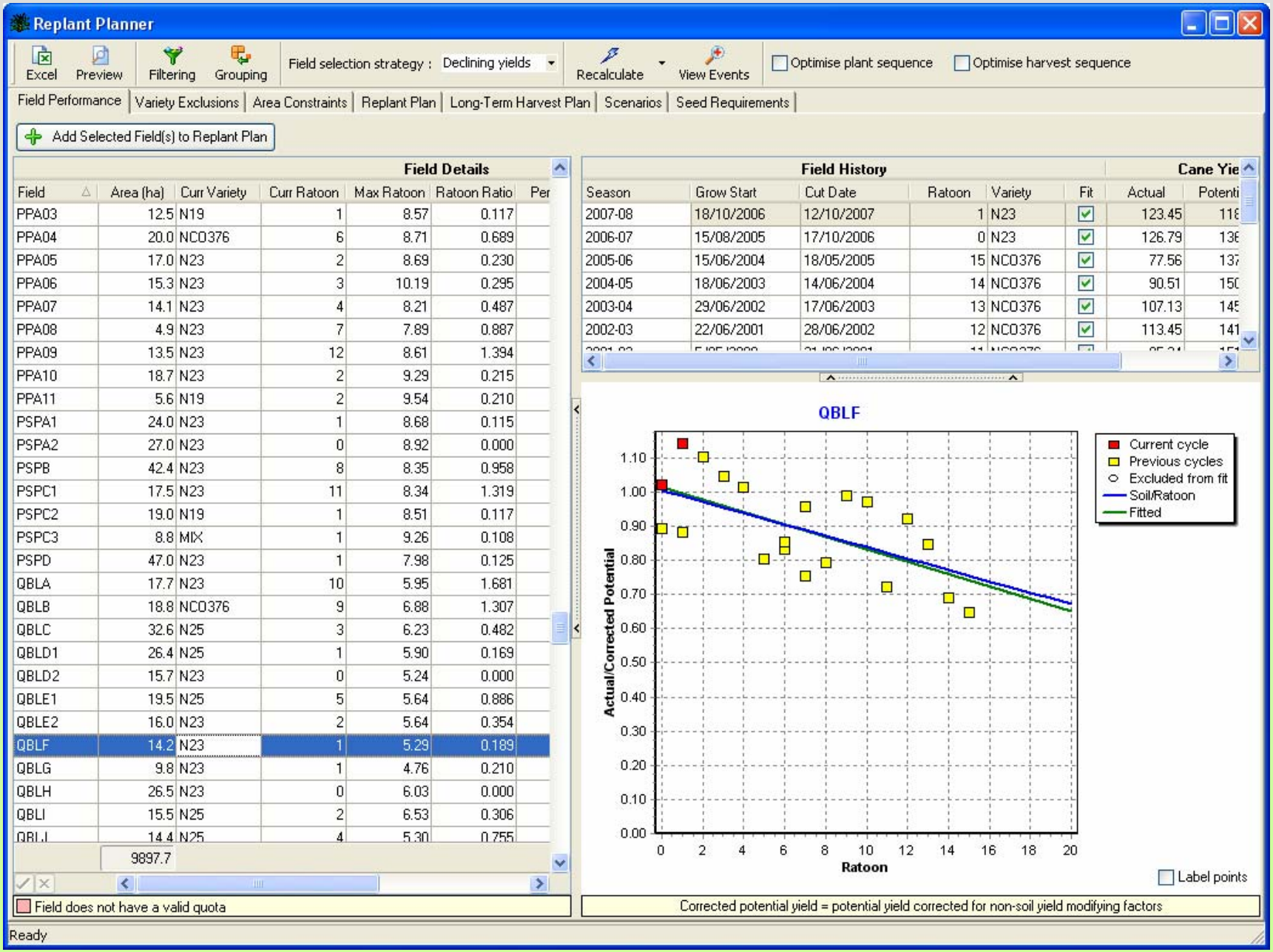
Add | Delete | Use Fitted Curve

Graph | Field Data



View : All sucrose curves | Show field data

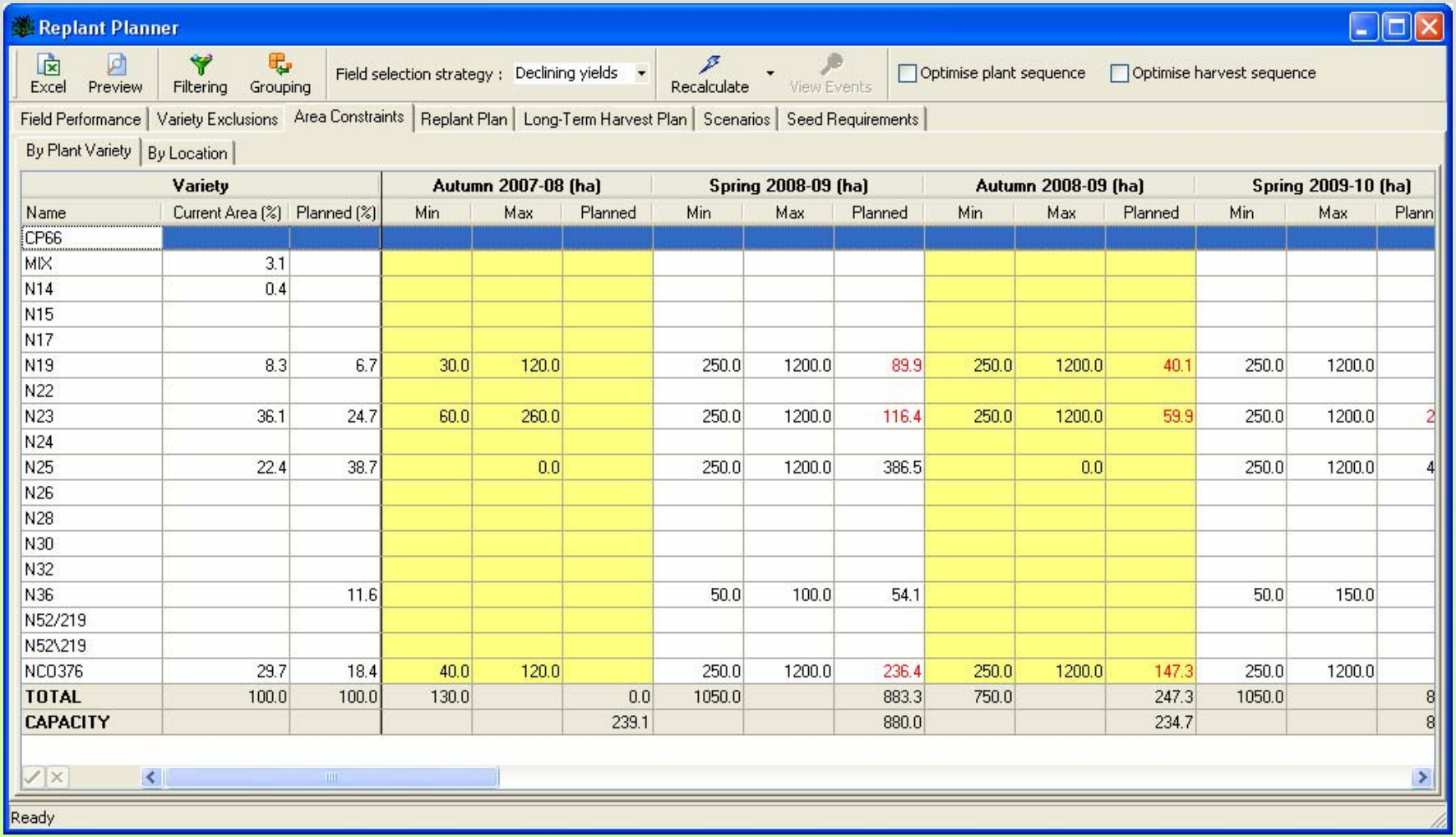
Step 2- Field Performance



Field	Area (ha)	Curr Variety	Curr Ratoon	Max Ratoon	Ratoon Ratio	Per
PPA03	12.5	N19	1	8.57	0.117	
PPA04	20.0	NCO376	6	8.71	0.689	
PPA05	17.0	N23	2	8.69	0.230	
PPA06	15.3	N23	3	10.19	0.295	
PPA07	14.1	N23	4	8.21	0.487	
PPA08	4.9	N23	7	7.89	0.887	
PPA09	13.5	N23	12	8.61	1.394	
PPA10	18.7	N23	2	9.29	0.215	
PPA11	5.6	N19	2	9.54	0.210	
PSPA1	24.0	N23	1	8.68	0.115	
PSPA2	27.0	N23	0	8.92	0.000	
PSPB	42.4	N23	8	8.35	0.958	
PSPC1	17.5	N23	11	8.34	1.319	
PSPC2	19.0	N19	1	8.51	0.117	
PSPC3	8.8	MIX	1	9.26	0.108	
PSPD	47.0	N23	1	7.98	0.125	
QBLA	17.7	N23	10	5.95	1.681	
QBLB	18.8	NCO376	9	6.88	1.307	
QBLC	32.6	N25	3	6.23	0.482	
QBLD1	26.4	N25	1	5.90	0.169	
QBLD2	15.7	N23	0	5.24	0.000	
QBLE1	19.5	N25	5	5.64	0.886	
QBLE2	16.0	N23	2	5.64	0.354	
QBLF	14.2	N23	1	5.29	0.189	
QBLG	9.8	N23	1	4.76	0.210	
QBLH	26.5	N23	0	6.03	0.000	
QBLI	15.5	N25	2	6.53	0.306	
QBLJ	14.4	N25	4	5.30	0.755	
	9897.7					

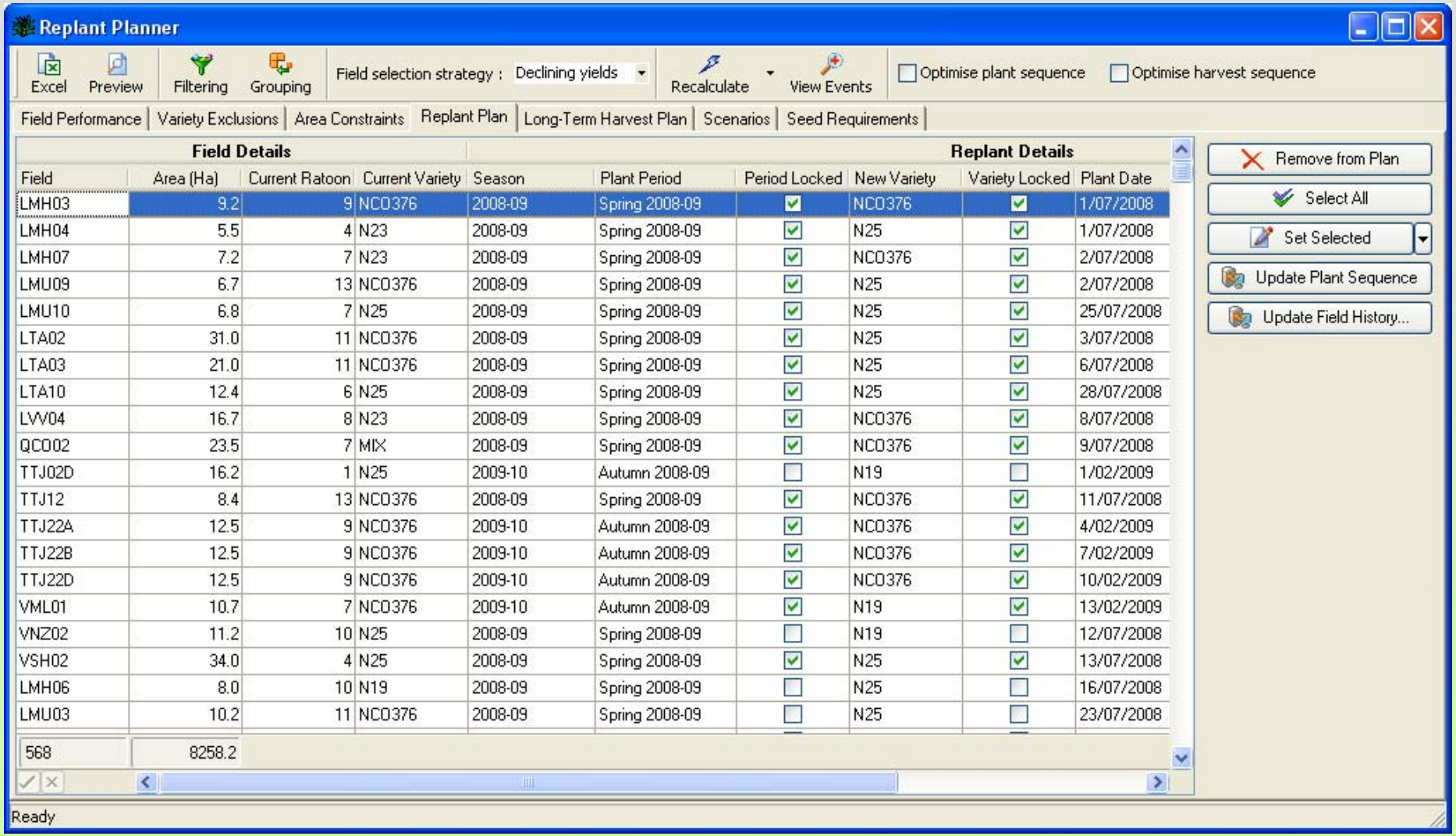
Season	Grow Start	Cut Date	Ratoon	Variety	Fit	Actual	Potenti
2007-08	18/10/2006	12/10/2007	1	N23	☑	123.45	118
2006-07	15/08/2005	17/10/2006	0	N23	☑	126.79	138
2005-06	15/06/2004	18/05/2005	15	NCO376	☑	77.56	137
2004-05	18/06/2003	14/06/2004	14	NCO376	☑	90.51	150
2003-04	29/06/2002	17/06/2003	13	NCO376	☑	107.13	145
2002-03	22/06/2001	28/06/2002	12	NCO376	☑	113.45	141

Step 2- Variety Constraints

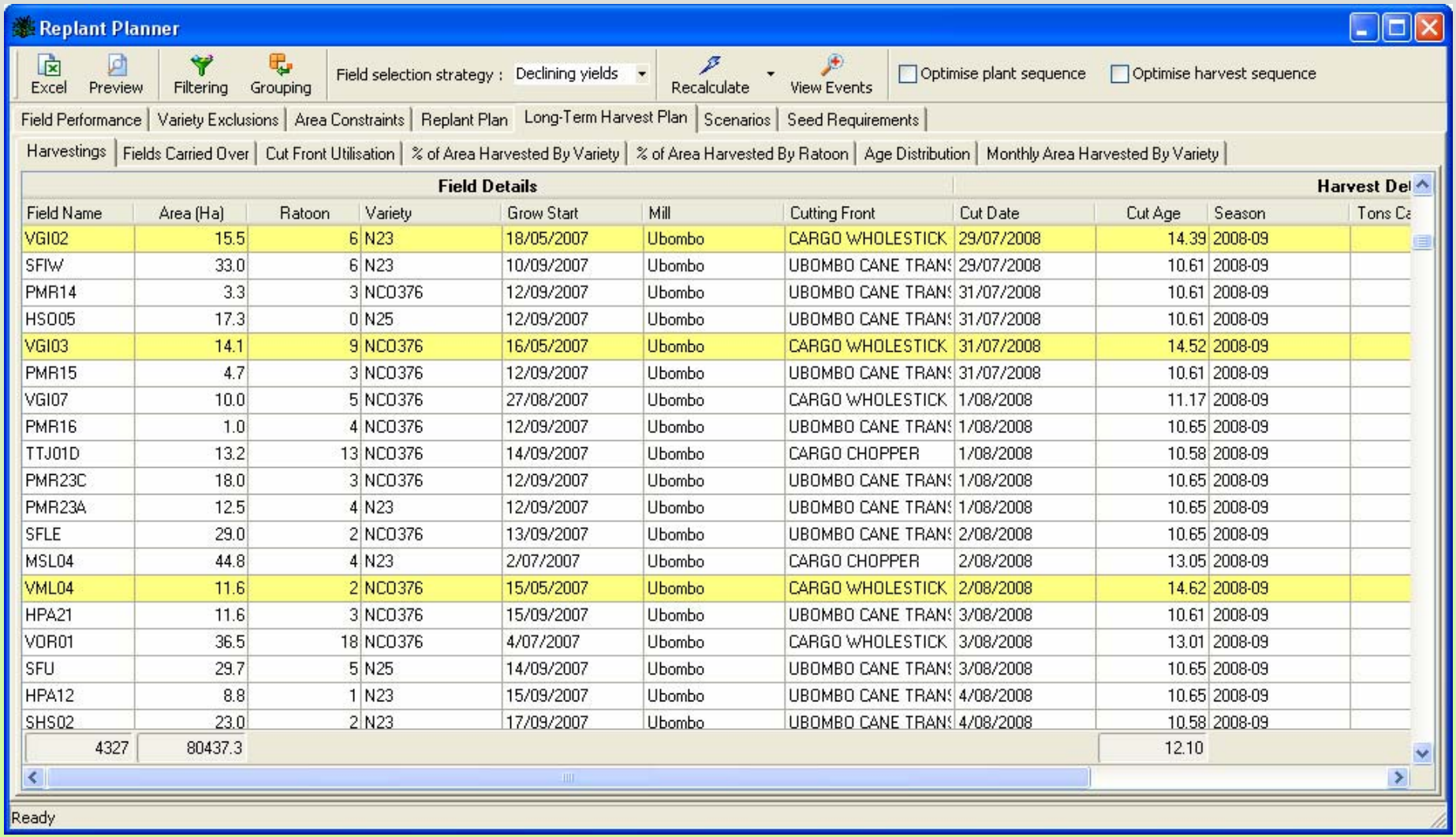


Variety			Autumn 2007-08 (ha)			Spring 2008-09 (ha)			Autumn 2008-09 (ha)			Spring 2009-10 (ha)		
Name	Current Area (%)	Planned (%)	Min	Max	Planned	Min	Max	Planned	Min	Max	Planned	Min	Max	Plann
CP66														
MIX	3.1													
N14	0.4													
N15														
N17														
N19	8.3	6.7	30.0	120.0		250.0	1200.0	89.9	250.0	1200.0	40.1	250.0	1200.0	
N22														
N23	36.1	24.7	60.0	260.0		250.0	1200.0	116.4	250.0	1200.0	59.9	250.0	1200.0	2
N24														
N25	22.4	38.7		0.0		250.0	1200.0	386.5		0.0		250.0	1200.0	4
N26														
N28														
N30														
N32														
N36		11.6				50.0	100.0	54.1				50.0	150.0	
N52/219														
N52\219														
NCO376	29.7	18.4	40.0	120.0		250.0	1200.0	236.4	250.0	1200.0	147.3	250.0	1200.0	
TOTAL	100.0	100.0	130.0		0.0	1050.0		883.3	750.0		247.3	1050.0		8
CAPACITY					239.1			880.0			234.7			8

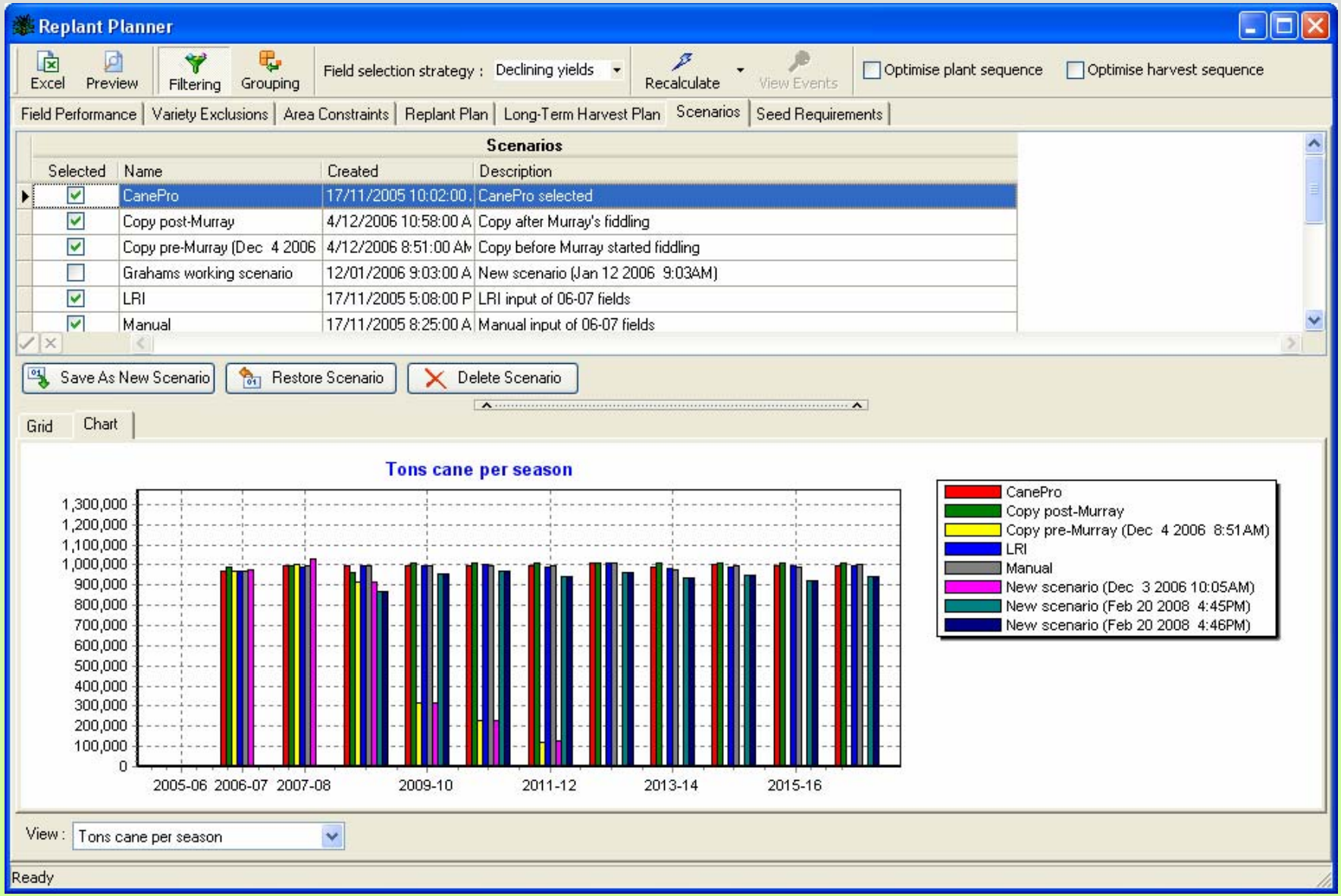
Step 3- Replant Plan



Step 3- Long Term Harvest Plan



Step 4- Scenarios



Advantages

- Improves replant field selection decisions
- Place varieties in the right time of the season to optimise overall season yield
- Optimise long-term harvest plan to minimize age effects
- Scenarios allow evaluation of decisions on overall sucrose yield

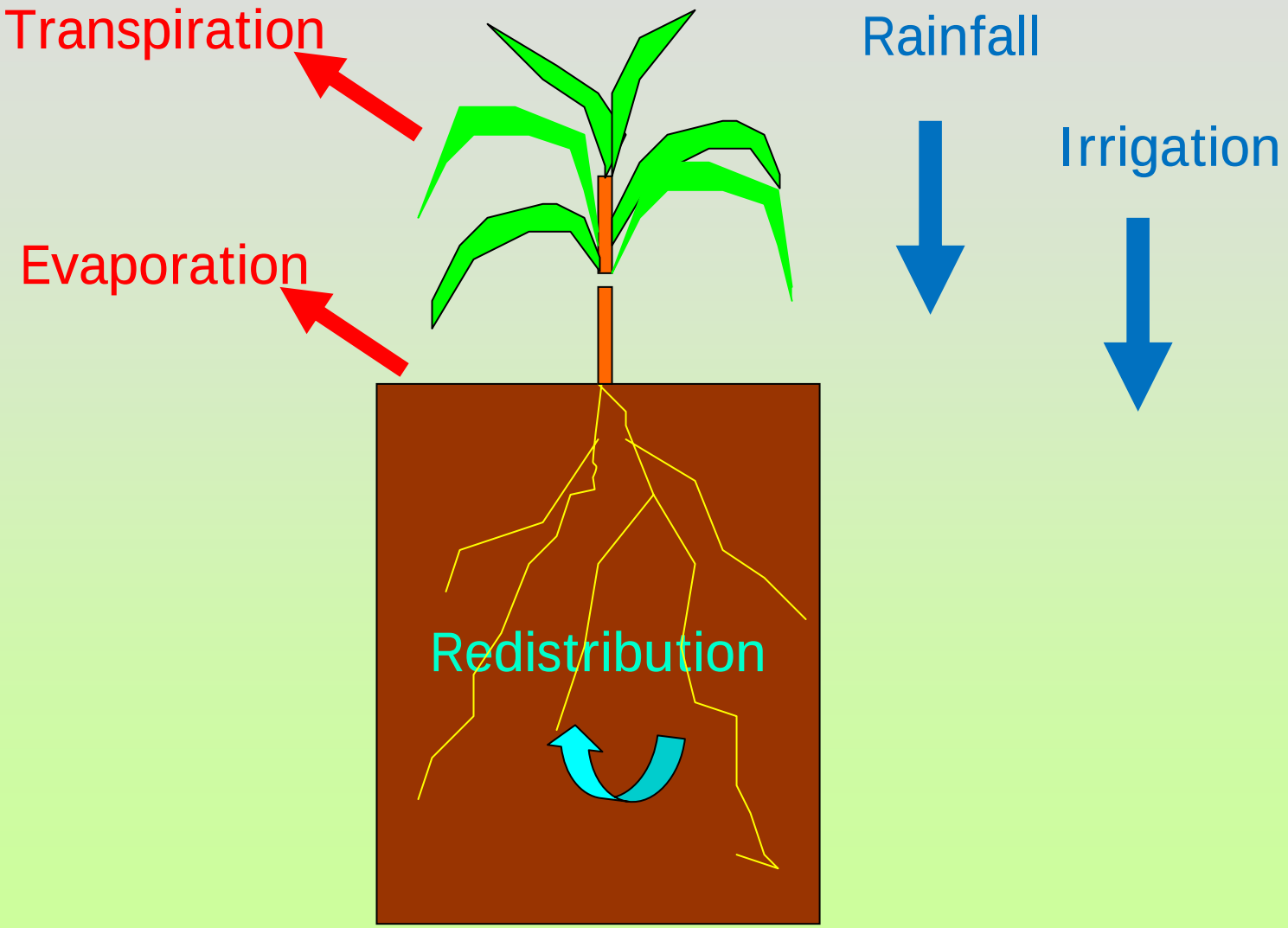
Examples of model use in commercial operations – CanePro Cane Management Software

5. Irrigation Scheduling

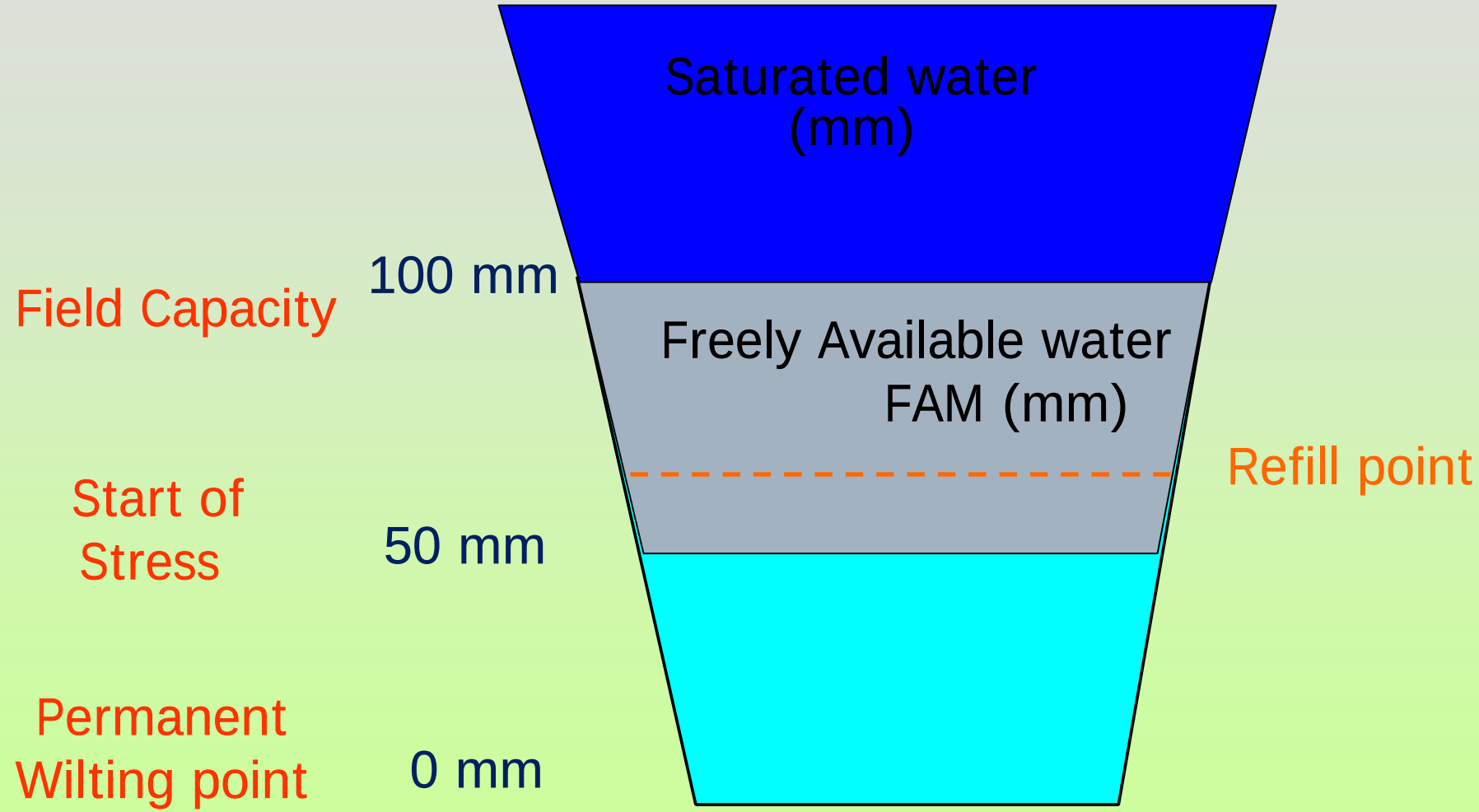
Irrigation Scheduling Concept

- Water balance
- Soil water concepts
- Estimating components of the water balance

Water Balance



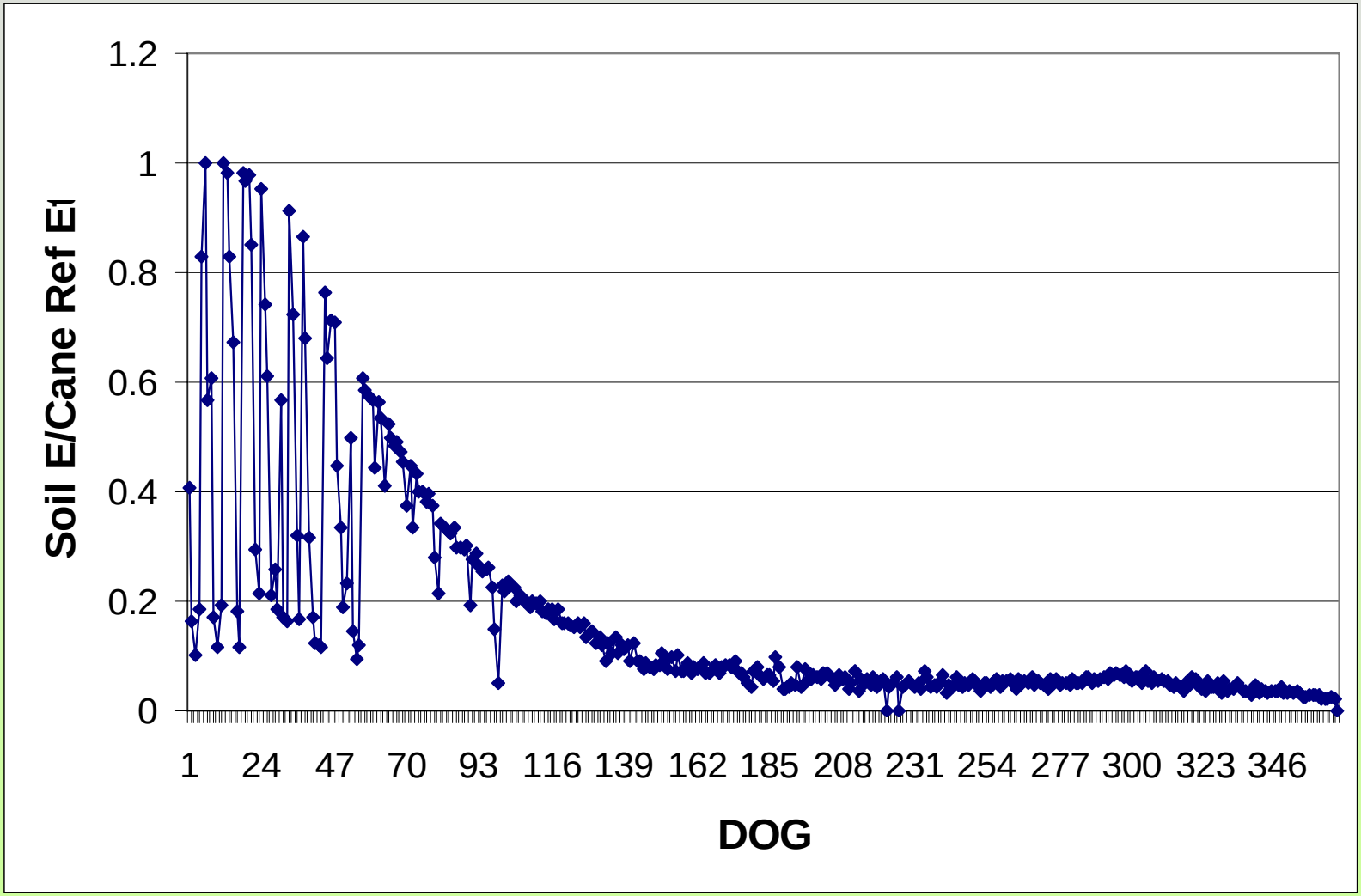
Soil Water Concepts



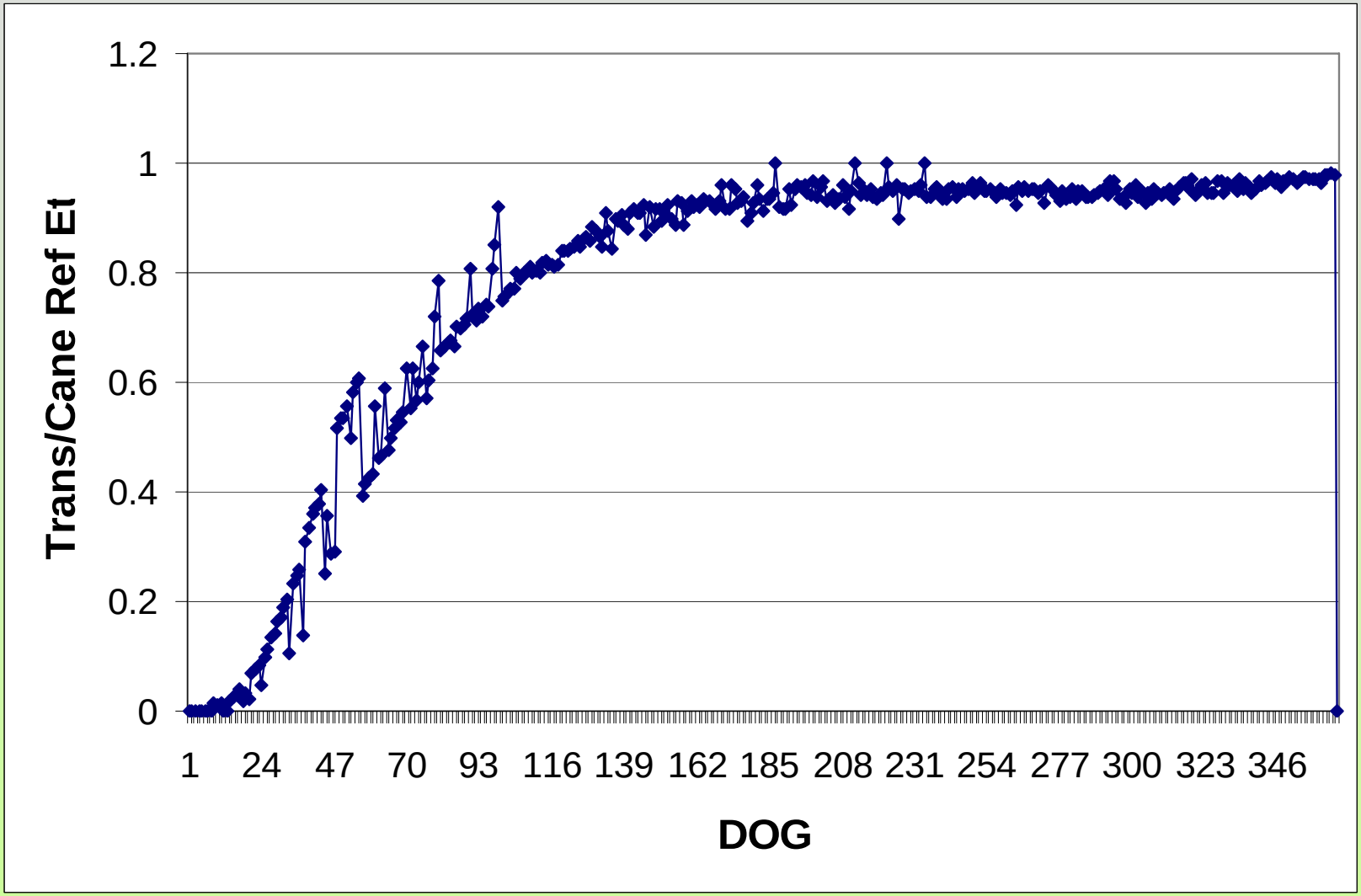
Estimating components of the water balance

- Evaporation + transpiration – Potential Et calculated using Penman-Monteith
- Soil evaporation calculated separately from transpiration
- Rainfall and estimate of net irrigation as direct inputs

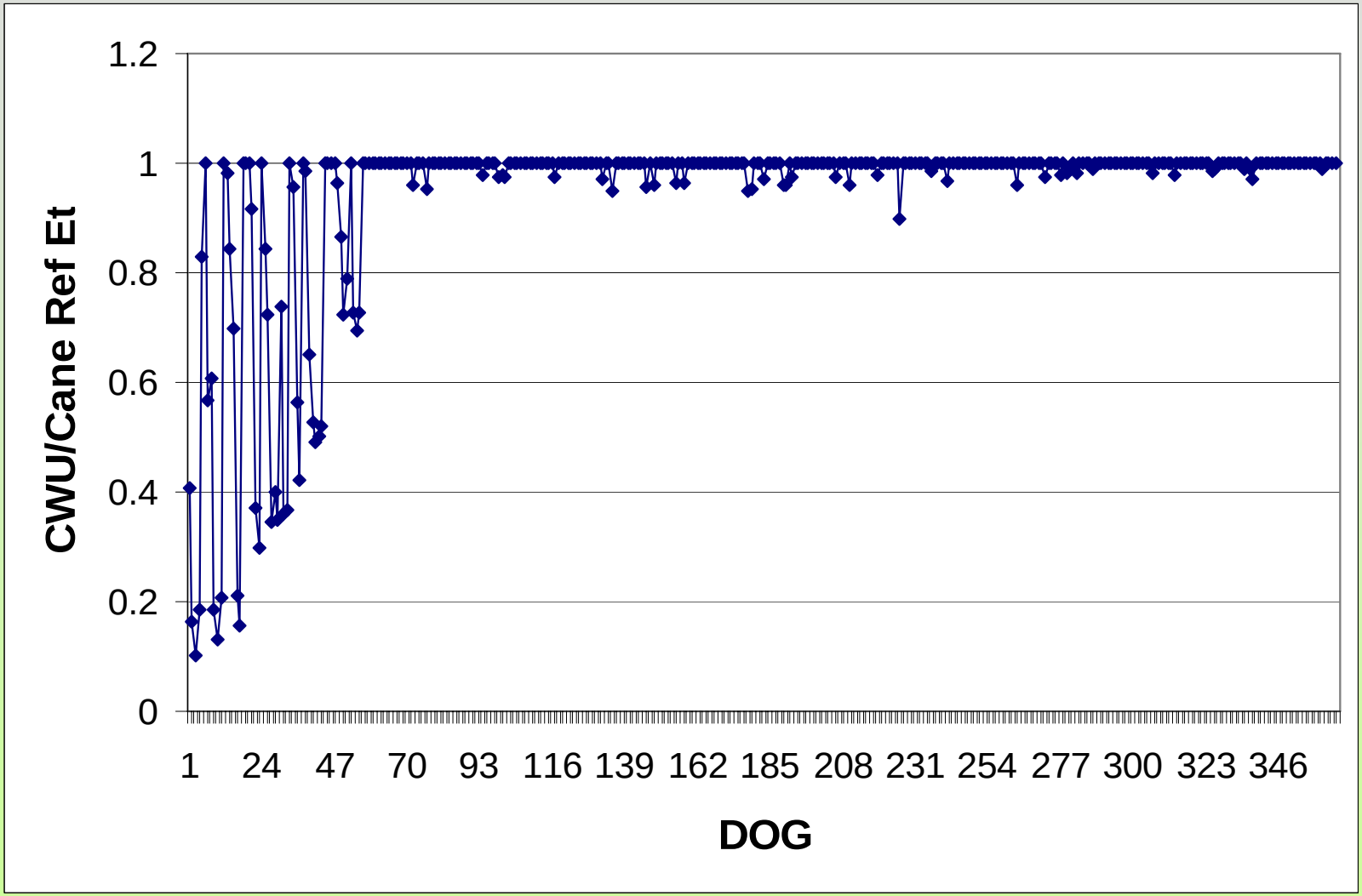
Soil Evap. as a % of Pot Et



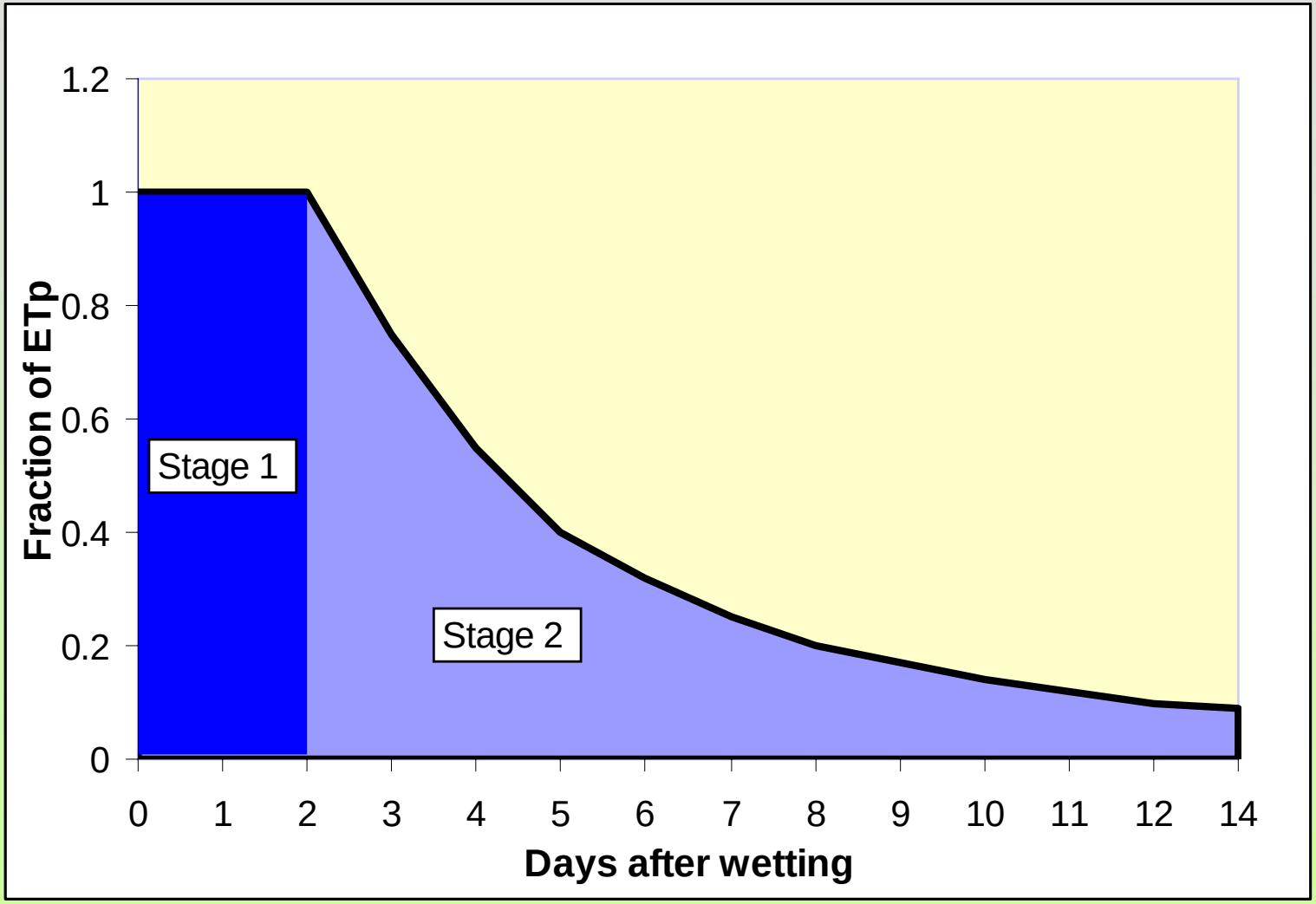
Transpiration as a % of Pot Et



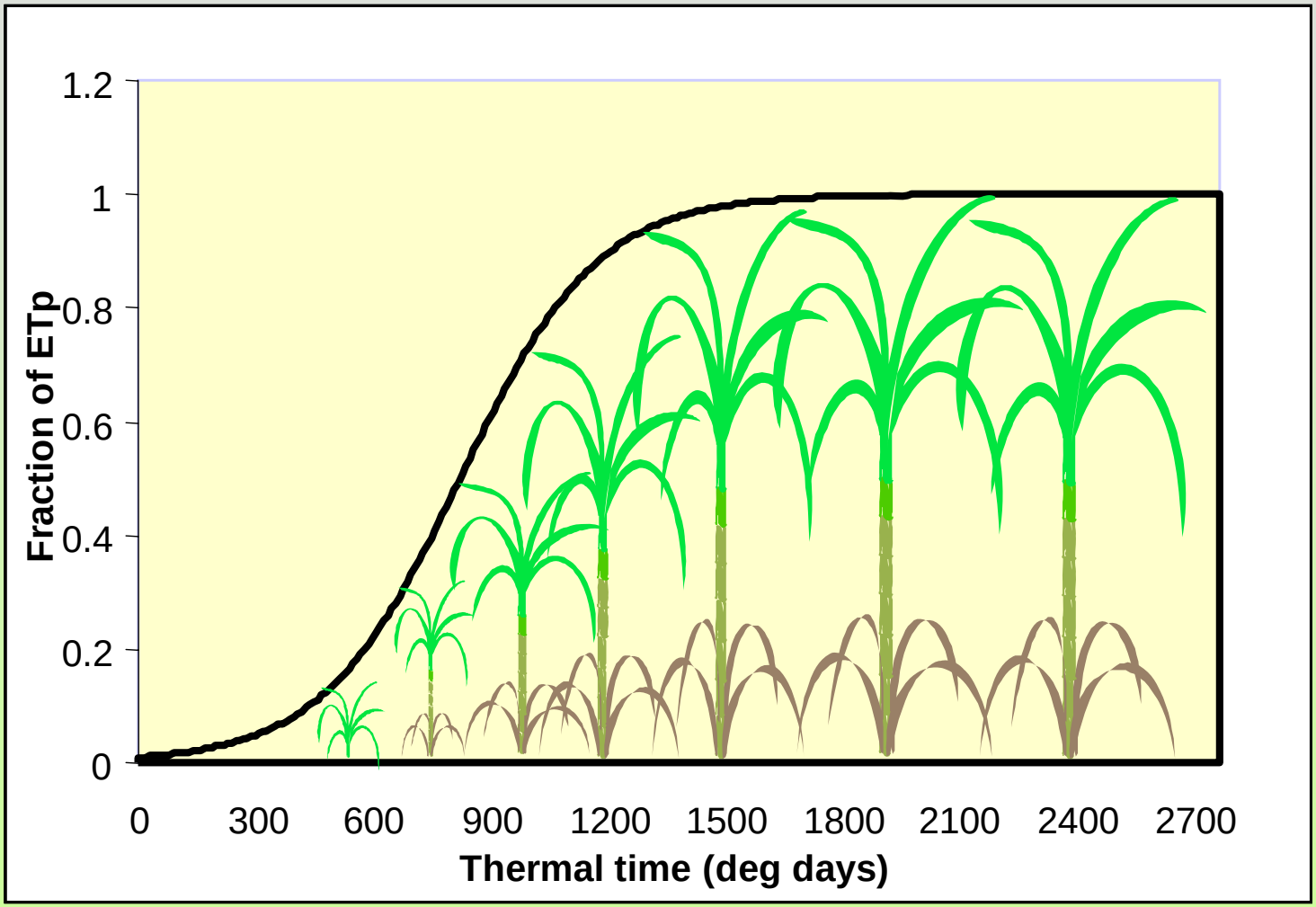
CWU as a % of Pot Et



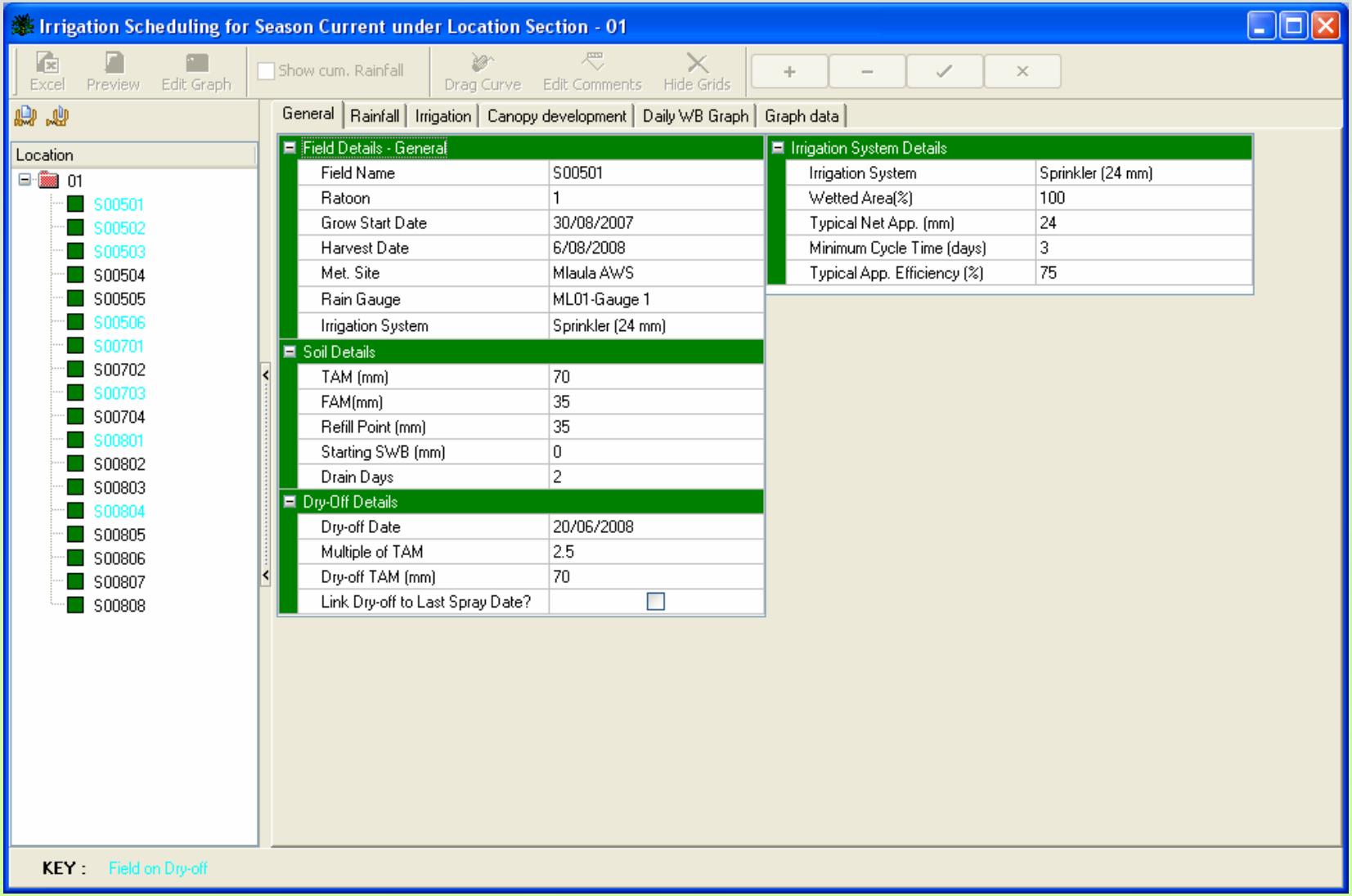
Two–Stage Soil Evaporation Model



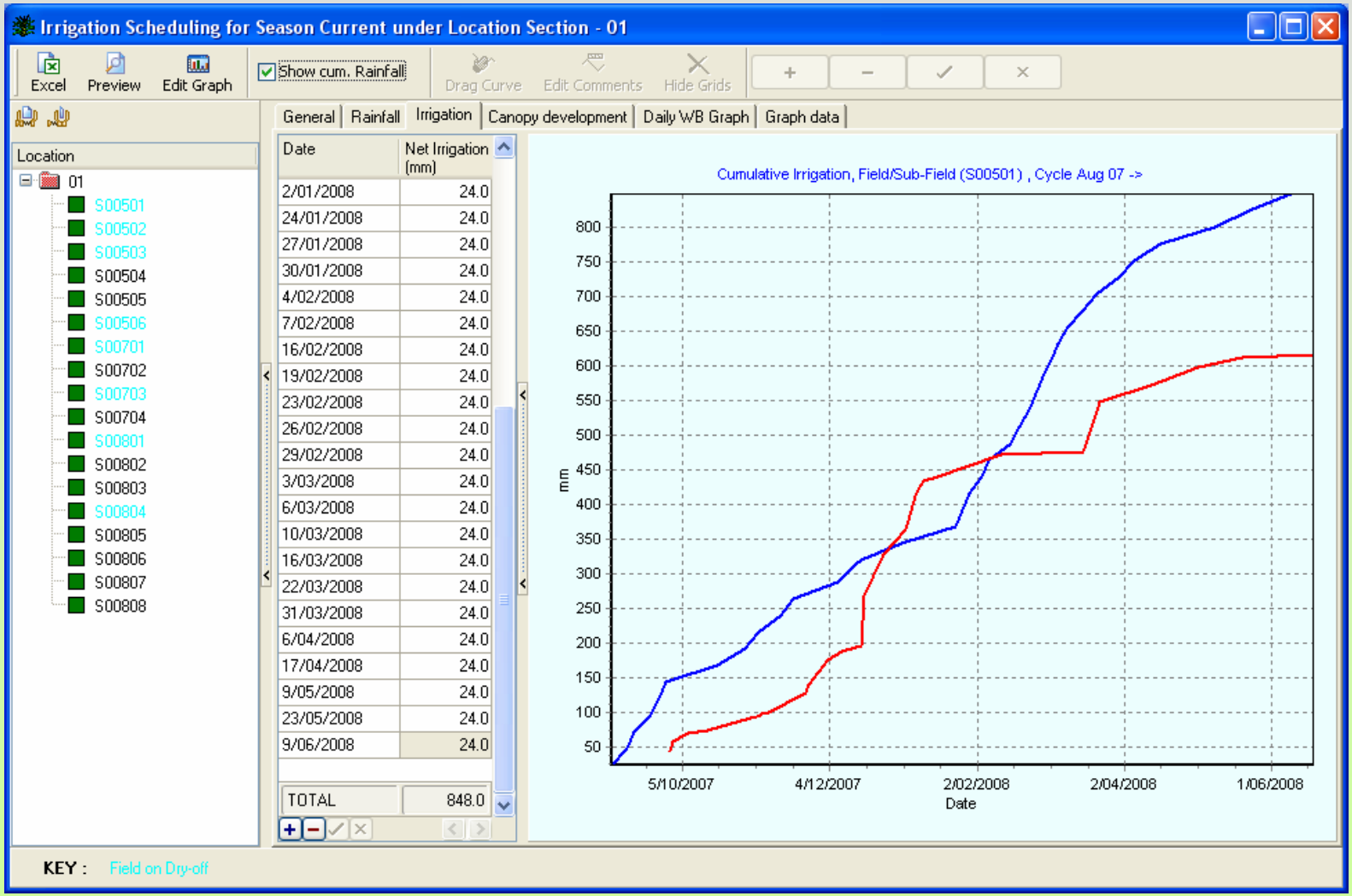
Transpiration – Thermal Time-based Canopy Development Model



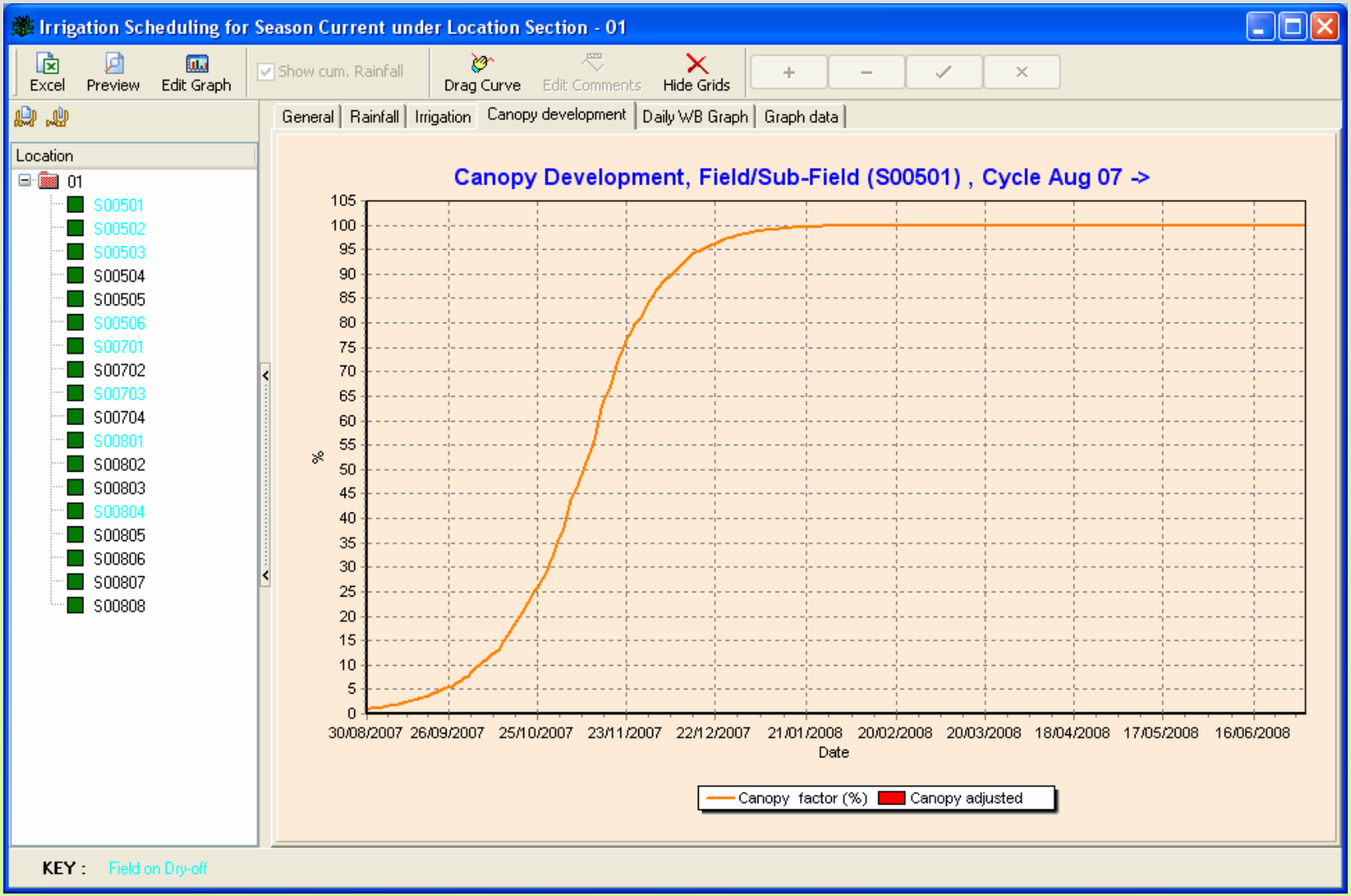
Field soil details



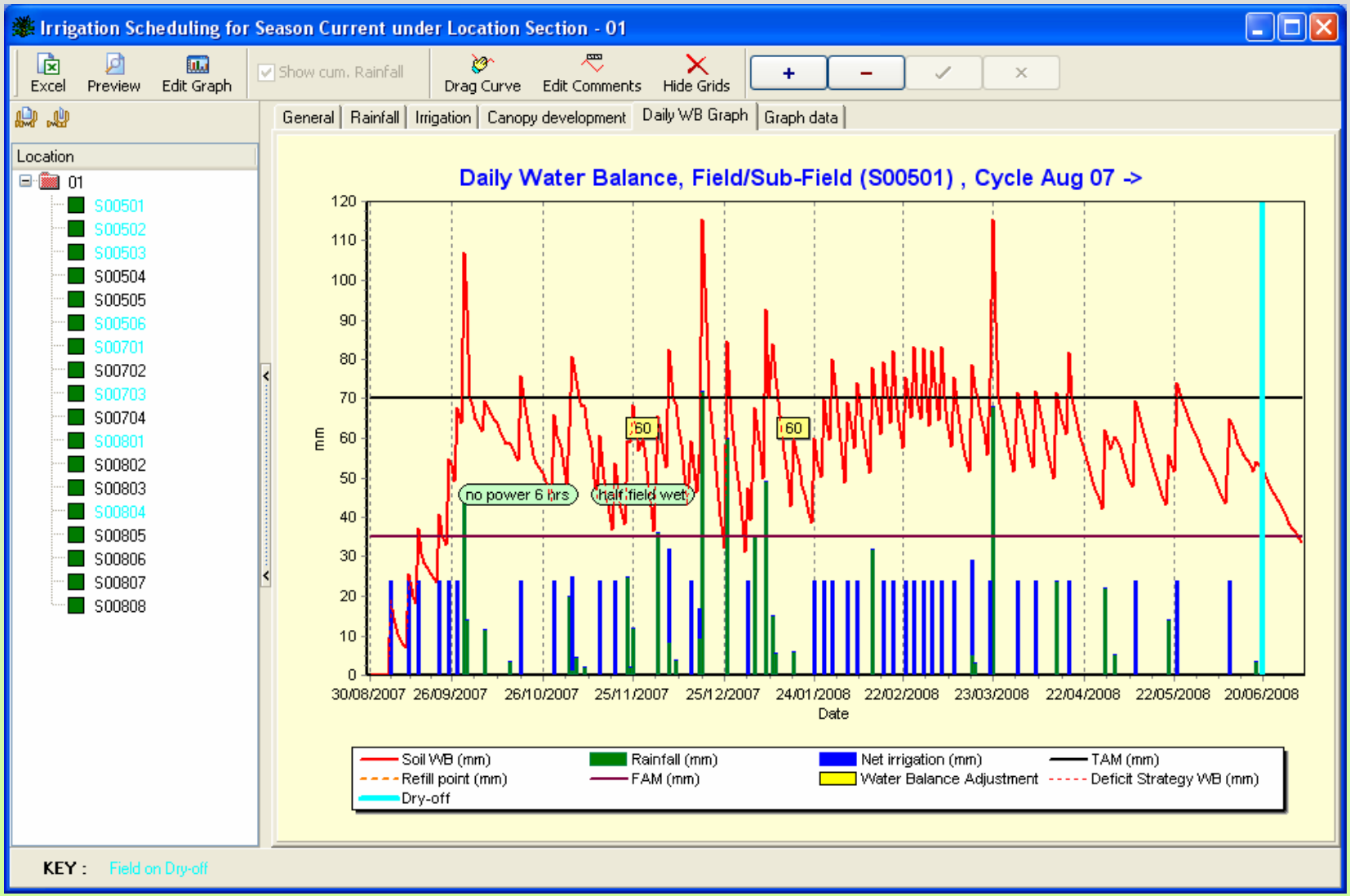
Irrigation & Rainfall



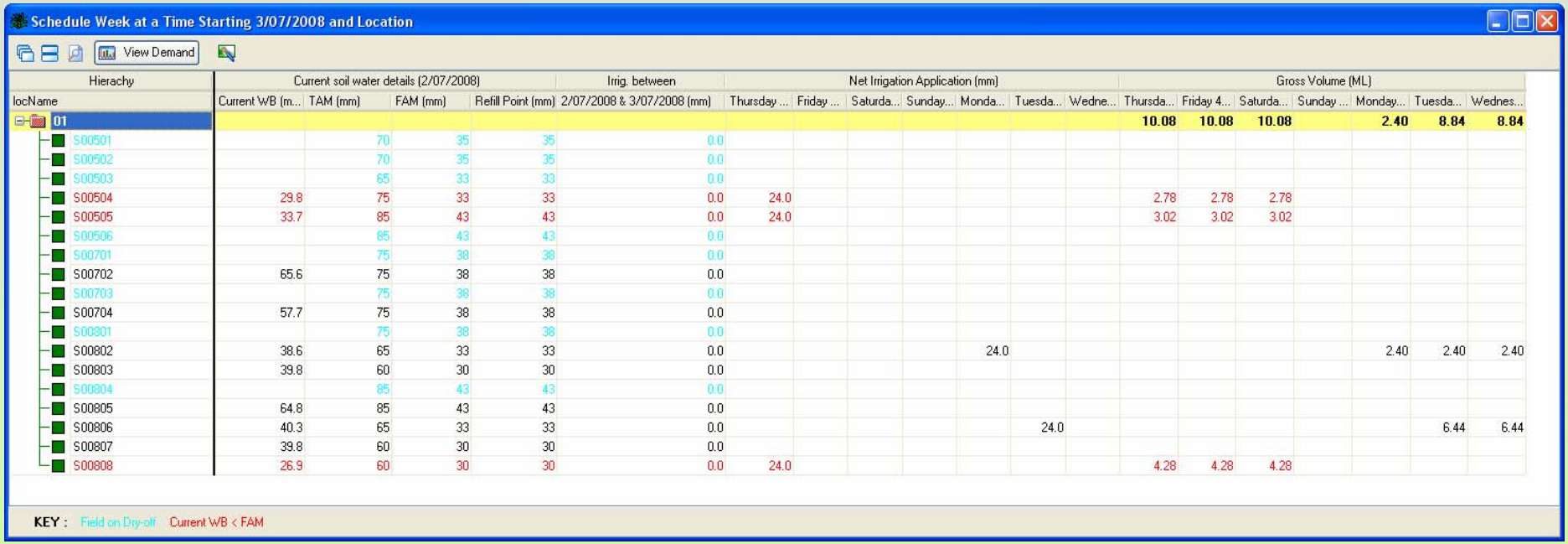
Canopy Development



Water balance



Weekly Schedule



Schedule Week at a Time Starting 3/07/2008 and Location

View Demand

Hierachy	Current soil water details (2/07/2008)				Irrig. between	Net Irrigation Application (mm)							Gross Volume (ML)						
locName	Current WB (m...	TAM (mm)	FAM (mm)	Refill Point (mm)	2/07/2008 & 3/07/2008 (mm)	Thursday ...	Friday ...	Saturda...	Sunday...	Monda...	Tuesda...	Wedne...	Thursda...	Friday 4...	Saturda...	Sunday ...	Monday...	Tuesda...	Wednes...
01													**10.08**	**10.08**	**10.08**		**2.40**	**8.84**	**8.84**
S00501		70	35	35	0.0														
S00502		70	35	35	0.0														
S00503		65	33	33	0.0														
S00504	29.8	75	33	33	0.0	24.0							2.78	2.78	2.78				
S00505	33.7	85	43	43	0.0	24.0							3.02	3.02	3.02				
S00506		85	43	43	0.0														
S00701		75	38	38	0.0														
S00702	65.6	75	38	38	0.0														
S00703		75	38	38	0.0														
S00704	57.7	75	38	38	0.0														
S00801		75	38	38	0.0														
S00802	38.6	65	33	33	0.0					24.0							2.40	2.40	2.40
S00803	39.8	60	30	30	0.0														
S00804		85	43	43	0.0														
S00805	64.8	85	43	43	0.0														
S00806	40.3	65	33	33	0.0						24.0							6.44	6.44
S00807	39.8	60	30	30	0.0														
S00808	26.9	60	30	30	0.0	24.0							4.28	4.28	4.28				

KEY : Field on Dry-off Current WB < FAM

Advantages

- Improve water use efficiency
- Raise awareness of irrigation on the estate
- Improve logistics of water-ordering

Conclusions

- Models have the ability to provide physiologically based decision-support tools to commercial operations
- Allows for wide adoption of new technology through client base
- Improve yields through better decisions
- Save costs through better monitoring and control